B.4 Variable Demand Model Development Report

SEMMMS A6 to Manchester Airport Relief Road

Model Development Report

Report for Stockport Metropolitan Borough Council

February 2012

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Primary Author:	Pete Kidd
Other Author(s):	Alison Daniels
Reviewer(s):	Nick Benbow
Formatted by:	Leticia Rodriguez

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Summary

This report documents the development of SEMMMS VDM, a multi-modal demand modelling system covering the geographical areas of Stockport, south Manchester and north Cheshire. This model has been developed with the sole aim of delivering a Major Scheme Business Case (MSBC) for the SEMMMS Manchester Airport to A6 Relief Road. SEMMMS VDM contains three components; MVA's bespoke variable demand model (VDM), SATURN highway assignment models and PT-TRIPS public transport models. This report documents the functionality of the models system, the production of the travel demand matrices, together with the calibration and validation of the SEMMMS VDM.

The demand model uses matrices that have been derived from validated matrices associated with the highway model and the public transport models. Those sub-models have their own demand matrices that have been calibrated and validated to local data including traffic counts, passenger counts and journey times.

The highway and public transport models are used to provide generalised cost matrices to the VDM as a basis for forecasting changes in travel choices relative to a reference case situation. The reference case reflects the impacts of demographic changes, but not the costs of travel. In turn the VDM modifies the assignment model matrices. The system iterates until supply and demand are in equilibrium.

This report also describes the calibration and validation of the demand model. It presents results from standard 'realism tests', tests that are specified in the Department for Transport's guidance TAG (Transport Analysis Guidance). The realism tests set target values for the elasticity of demand to cost changes. The approach taken to calibration of the demand model was to import parameters from the illustrative values presented in TAG and adjust them to produce reasonable results in the realism tests. This approach produced a reasonable model, with overall elasticity values within the target range for both the realism tests.

With the parameters taken from within the ranges of the illustrative values, the elasticity of car vehicle kilometres to fuel price was -0.28, within the target range of -0.25 to -0.35. The public transport fare trip elasticity of -0.40 was within the target range of -0.2 to -0.9. Acceptable elasticity values disaggregated by purpose and time of day are presented. The car journey time trip elasticity of -0.20 was much less than the maximum allowable value of -2.0.

As described in the remainder of this report we judge that SEMMMS VDM is a suitable tool to inform the appraisal of the SEMMMS A6 to Manchester Airport Relief Road.

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1 Introduction

1.1 Context

1.1.1 A consortium of local authorities (Stockport Metropolitan Borough Council, Manchester City Council and Cheshire East Council) and Manchester Airport Group has been working between 2010 and 2012 to prepare a submission to DfT for part-funding of the SEMMMS A6 to Manchester Airport Relief Road (see Figure 1.1). The scheme is based on the recommendations of the South East Manchester Multi Modal Strategy (SEMMMS) commissioned by central government in 1998, which highlighted a number of transport improvement opportunities that would benefit the local area. The relief road was a key element of that strategy and is designed to improve surface access to, from and between Manchester Airport and local town and district centres and employment sites, reduce the impact of traffic congestion on communities in Stockport, South Manchester and Northeast Cheshire, regenerate these communities through reduced severance and improved accessibility, and provide an improved route for freight.

1.1.2 The proposed scheme, illustrated schematically in Figure 1.1, will connect the A6 at Hazel Grove with the M56 at Manchester Airport. It consists of approximately 10 km of new dual two lane carriageway and seven new junctions, and will also incorporate the existing 4 km section of the A555 dual carriageway to the south of Bramhall.

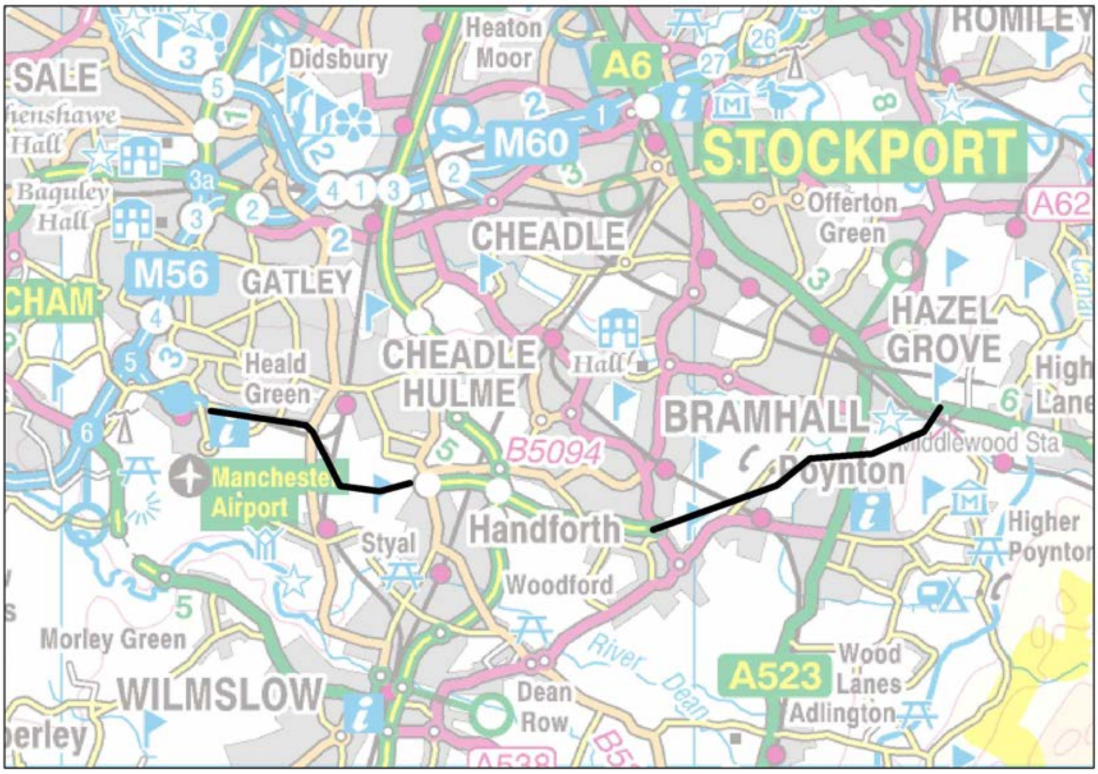

Figure 1.1 SEMMMS A6 to Manchester Airport Relief Road

1.1.3 To this end, MVA Consultancy were initially commissioned in February 2010 to construct a transport model system fit for the purpose of providing modelling inputs for a Major Scheme Business Case (MSBC) of the SEMMMS Relief Road to the Department for Transport (DfT), which was subsequently updated in February 2012. This system has been developed and subsequently used to provide demand forecasts of the SEMMMS Relief Road, as well as inputs for operational analyses, and economic and environmental appraisal. MVA considers this system fit for the purpose of assessing the impacts of the SEMMMS Relief Road and a primary consideration during the preparation of this report has been to demonstrate how the system complies with the DfT modelling requirements, as set out in the Transport Analysis Guidance (TAG).

1.2 SEMMMS Variable Demand Model

1.2.1 The model system is known as SEMMMS Variable Demand Model (SEMMMS VDM) and has a base year of 2009. SEMMMS VDM combines MVA's bespoke demand model with validated SATURN highway (Atkins / Leeds ITS software) and PT-TRIPS public transport (Citilabs software) average hour assignment models.

1.2.2 SEMMMS VDM makes use of data sources, data structures and functional algorithms similar to those used in the GMSPM2 model system, which was used successfully to provide supporting evidence for AGMA's Transport Innovation Fund (TIF) bid of 2007. Since 2007 MVA has enhanced its demand modelling software in order to improve the consistency between travel costs estimated in the detailed assignment models and the costs which are input to the demand model. The key enhancement to the specification of SEMMMS VDM over that of GMSPM2 is the removal of the spatial tier, as cost skims from the highway and public transport assignment models are fed directly into the demand model. In contrast, GMSPM2 took a hierarchical approach to model formulation (TAG 3.1.2C, 2.4.7), consisting of two tiers. The upper tier contained a demand model with a spatially aggregate supply representation, whilst the lower tier contained a more spatially detailed supply representation. Considerable resource was required during the construction of GMSPM2 to demonstrate consistency of travel costs between the supply models in its upper and lower tiers, a task which was not required when developing the 'aggregate' model structure of SEMMMS VDM.

1.3 This and Associated Reports

1.3.1 This report describes the development and calibration of SEMMMS VDM and contains the following chapters:

- chapter 2 – The Need for Variable Demand Modelling;
- chapter 3 – Geographic Scope and Zoning;
- chapter 4 – Model Dimensions;
- chapter 5 – Base Year Travel Demand;
- chapter 6 – Demand Model Processes; and
- chapter 7 - Demand Model Calibration.

1.3.2 Three other documents should be read in conjunction with this report and provide supporting information about the SEMMMS VDM system:

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- SEMMMS8 SATURN Local Model Validation Report (LMVR) produced by Transport for Greater Manchester (TfGM) Highways Forecasting & Analytical Services (HFAS) in February 2012;
- SEMMMS8 PT-TRIPS LMVR produced by MVA in February 2012; and
- Forecasting Note produced by MVA in February 2012.

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2 The Need for Variable Demand Modelling

2.1 Introduction

2.1.1 In this chapter we review the need for and scope of variable demand modelling to support the appraisal of the SEMMMS Relief Road.

2.2 Area of Influence

2.2.1 MVA has specifically designed SEMMMS VDM with a view to providing supporting evidence for the MSBC of the SEMMMS Relief Road. The SEMMMS scheme connects the M56 at Manchester Airport with the A6 at Hazel Grove. Although SEMMMS VDM contains demand and supply representations covering much of the north of England, the primary focus of the model system coincides with the smaller Area of Influence (AofI) of the scheme (see Figure 2.1), covering parts of South Manchester and Cheshire East. The AofI was determined using a preliminary version of the SATURN model to identify the area over which traffic flows changed significantly when the SEMMMS scheme was introduced.

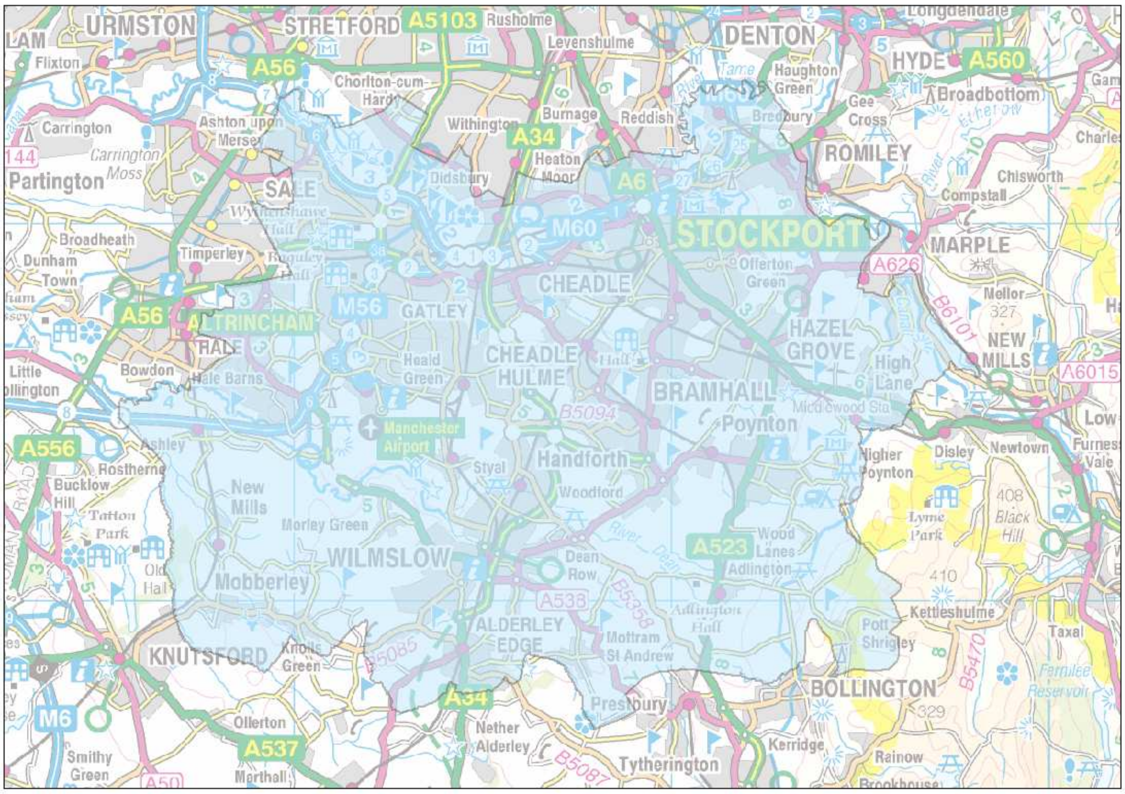

Figure 2.1 SEMMMS Relief Road Area of Influence

2.2.2 The AofI is the part of the model for which most attention has been placed on network coding, density and validation. Beyond the AoI, network coding and demand representation extends, albeit with decreasing levels of detail, across the rest of Greater Manchester, Cheshire, Yorkshire, Humberside and the East Midlands. The remainder of Great Britain is represented at a very coarse level of detail. Computing restrictions (memory and run times), and the availability of data on travel patterns, inevitably limit the spatial detail to which travel can be represented.

2.3 VDM Applications

2.3.1 The system of models has been configured to allow the scheme to be assessed under a number of scenarios that reflect the interaction of changes in incomes, car ownership, household structure, development patterns and travel costs (time and money) for future years.

2.3.2 The primary outputs from SEMMMS VDM include:

- levels of travel demand by time of day, mode of travel, geographic distribution, reason for travel and the availability of a car;
- time and money costs of travel; and
- levels of traffic on roads within the modelled area.

2.3.3 These outputs can be used to analyse:

- road speeds and congestion;
- traffic related noise and emissions;
- transport economic impacts of the scheme, accounting for changes in travel time and cost;
- road traffic accidents;
- the accessibility of workplaces for employees, and conversely the available supply of labour for employers; and
- wider economic benefits resulting from the scheme.

2.4 The Importance of Variable Demand Modelling

2.4.1 TAG 3.10.1, 1.2.1 states that any change in transport conditions causes, in principle, a change in demand. The purpose of variable demand modelling is to predict and quantify these changes. The Standing Advisory Committee on Trunk Road Appraisal (SACTRA) reporting in 1994 emphasised the importance of establishing a realistic scenario in the absence of the scheme or strategy, the extent of travel suppression in the 'without-scheme' case, and the extra traffic induced in the 'with-scheme' case (TAG 3.10.1, 1.2.2).

2.4.2 SEMMMS VDM reflects distribution, mode choice and macro time of day responses to changing travel conditions. The inclusion of these travel choice responses is arguably most important for producing realistic future year forecasts 'without-scheme', which reflect travellers response to changes in for example congestion, vehicle operating costs and public transport fares. However, one would also expect distributional impacts and to a lesser extent modal and time responses in the 'with-scheme' case.

2.5 The Need for and Scope of Variable Demand Modelling for SEMMMS

2.5.1 TAG 3.10.1, 1.3.1 suggests that fixed demand (rather than variable) assessments may be acceptable if the following criteria are satisfied:

- The scheme is quite modest both spatially and in terms of its effect on travel costs. Schemes with a capital cost of less than £5 million can generally be considered as modest.
- There is no congestion on the network in the forecast year.
- The scheme will have no appreciable effect on competition between private and public transport in the corridor containing the scheme.

2.5.2 Assessing these criteria in the context of the SEMMMS scheme indicates the need for variable demand modelling as:

- the scheme is likely to have considerable effects on travel costs and has capital costs very much greater than £5 million;
- there is traffic congestion in the base and forecasts year network; however
- the scheme might be expected to have a small effect on competition between private and public transport in the corridor containing the scheme.

2.5.3 TAG Unit 3.10.2 provides guidance on the specification of VDMs under different circumstances. This unit is clear that when a VDM is required:

- destination choice modelling must be undertaken, and the zone system should be designed to support this;
- representing demand in production/attraction (PA) format is strongly preferred to origin/destination (OD) format;
- the forecasting process should first use socio-economic data to modify the base year demand matrices, and then a VDM to represent the impact of changes in travel costs;
- demand must be adequately segmented (by car availability and journey purpose) into groups for which the impacts of changes in travel conditions over time and of policies can be assumed to be similar;
- a highway assignment model must be included so that changes in route choice, traffic levels and highway travel times and costs can be predicted;
- the model must be divided into time periods so that variations in travel conditions across the day can be represented; and
- travel demand choices should be influenced by the generalised cost of travel which is a combination of both time and money costs.

2.5.4 SEMMMS VDM is designed to be consistent with the requirements summarised above, and the detailed specification is provided in subsequent chapters of this report. A number of decisions were required regarding the functionality which we have taken after consulting TAG and which are summarised below:

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- Walk and cycle trips are included in the model so that there is no requirement to include a trip frequency (how often to travel) response. Transfer between these 'slow modes' and public transport can be significant, its inclusion makes the model more realistic and assists with calibrating the model's response to fare changes.
- A mode choice model is included. TAG includes recommendations on the appropriate fuel cost elasticity which should be achieved but which assume that all demand responses are available. We are not aware of any evidence regarding the appropriate elasticity for a model which omits mode choice. Inclusion of a mode choice model will also allow for potential impacts of the change in competition between car and public transport to be assessed.
- Inclusion of a mode choice response requires a matrix of public transport demand and for a mechanism to calculate public transport generalised costs. We have therefore included a PT-TRIPS assignment model which provides a transparent and internally consistent method for calculating public transport costs reflecting changes in fares and bus speeds over time and as a result of the scheme.
- Choice between 'macro' time periods (of several hours) is included as the travel costs in each period will be expected to change over time, and potentially to a lesser extent as a result of the scheme. Travel demand in the peak periods is more constrained by capacity than in the off peak periods, so over time we would anticipate that peak and off peak travel times would change at different rates.
- TAG 3.10.3, 1.4.12 states that 'peak spreading is mainly a micro response and represents travellers adjusting their travel behaviour without substantially altering their preferred arrival time or the timing of their destination activities'. To date, apart from some specialist small scale modelling no practical approach to modelling peak spreading has been developed. It would be possible to represent micro-time of day choice through the inclusion of more time periods in the supply and demand models but this would lead to very substantial increases in run times, and there are behavioural theory objections to using logit models for peak spreading. Consequently, MVA have decided not to explicitly model shoulders of the morning and evening peaks in SEMMMS VDM or to include a peak spreading response.

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2.6 Model System Overview

2.6.1 The SEMMMS VDM system operates using an 'aggregate' modelling approach as shown in Figure 2.2. The system consists of MVA's demand model and average hour SATURN highway and PT-TRIPS public transport assignment models, representing 4 time periods cumulatively covering 16 hours of the day.

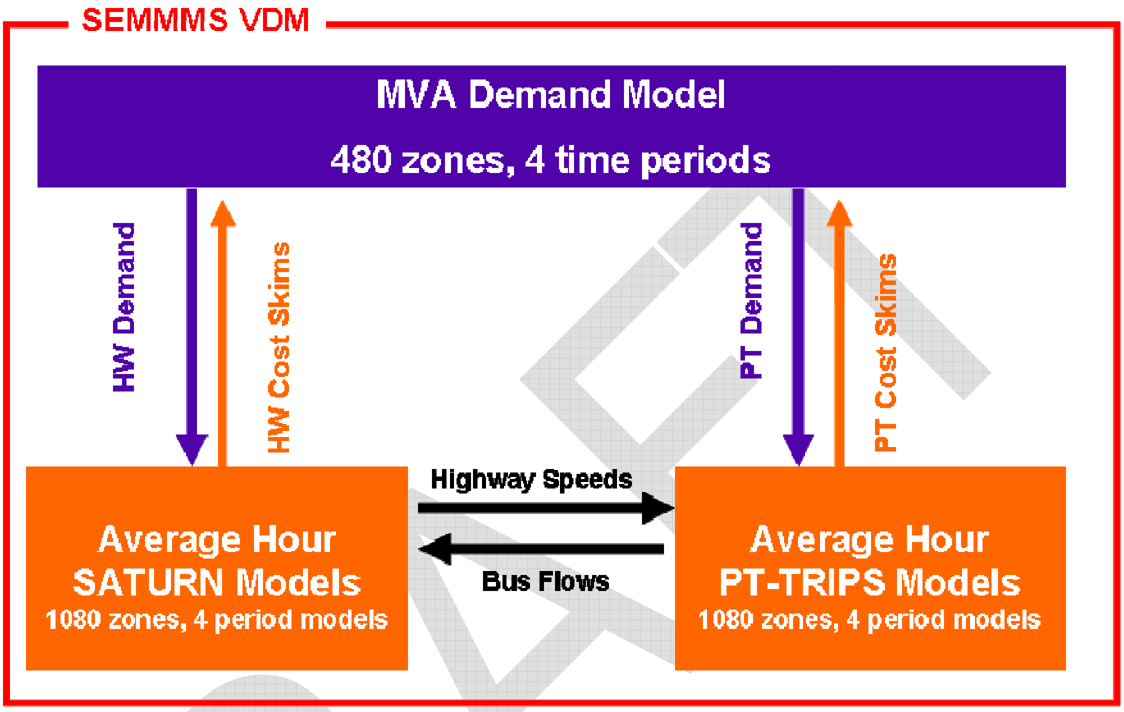

Figure 2.2 SEMMMS Variable Demand Model (SEMMMS VDM)

2.6.2 The assignment models are used to provide cost skims for input to the demand model with forecast demands from the demand model being reassigned in the assignment models. The demand and supply models are run iteratively until a converged solution is reached (as measured using the %GAP indicator specified by DfT).

2.6.3 A question therefore arises whether to input costs skims from average hour assignment models into the demand model or cost skims from peak hour assignment models. Use of cost skims from the average hour assignment models will likely underestimate congestion impacts within the demand model for peak hours whereas use of cost skims from peak hour assignment models will overestimate congestion impacts in the shoulders of the peaks. MVA are of the opinion that neither approach is ideal, each being a simplification of the traffic profiles that occur across a peak period. We have chosen to develop average hour assignment models to incorporate into the iterative supply/demand loops so that the travel costs for a time which are input to the demand model are derived by assigning the level of demand in that time period. This decision has added benefits in terms of reducing run time as assignments with lower flows tend to converge more quickly.

2.6.4 Demand changes from the converged SEMMMS VDM demand/supply system are then used to adjust the peak hour SEMMMS8 SATURN models (see Figure 2.3) which were developed by TfGM HFAS. Cost skims from the peak hour SEMMMS8 SATURN models are ultimately used

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in the economic appraisals. We proposed to use average hour modelling in SEMMMS VDM and peak hour modelling for final analysis so that:

- SEMMMS VDM includes demand for all times of day where there is significant trip making;
- SEMMMS VDM can be used to predict allocation of travel between time periods;
- peak hour SEMMMS8 SATURN assignment models can provide information for analysing operational conditions in the peak hours; and
- travel time changes used for economic appraisal are taken from the peak hour SEMMMS8 SATURN assignment models, being more accurate because traffic levels are more constant within the peak hours than across periods.

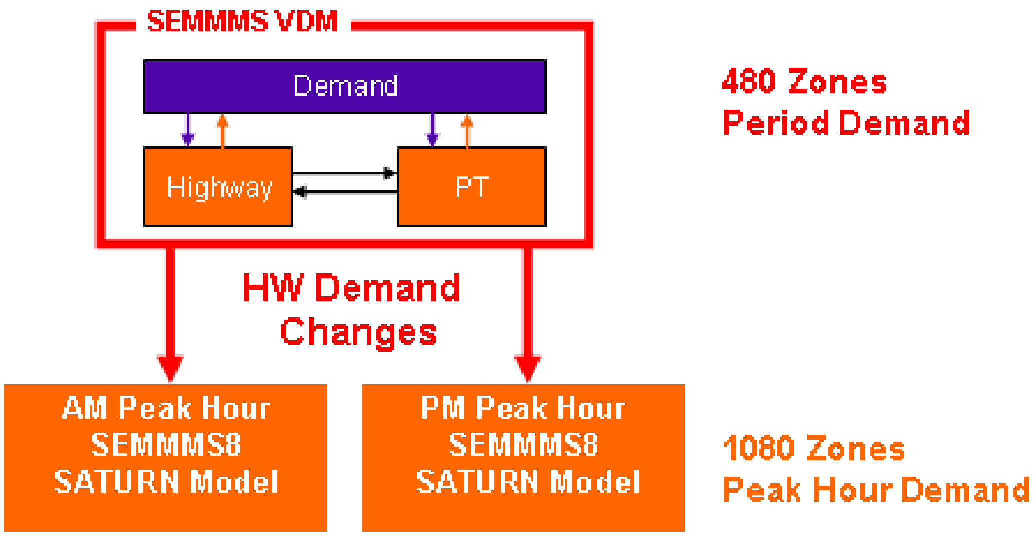

Figure 2.3 Forecast Demand Changes from SEMMMS VDM are applied to AM and PM Peak Hour SEMMMS8 SATURN Highway Assignment Matrices (both SEMMMS VDM and SEMMMS8 SATURN IP matrices are for an average hour)

2.6.5 TAG 3.1.2, 2.4 describes a tiered system as having supply representations in the upper and lower tiers that operate at different levels of spatial aggregation. This is not the structure of SEMMMS VDM, in which demand-weighted costs from 1080 zone average hour assignment models are aggregated to 480 zones for use in the demand model. As described later there is a one-to-one relationship between supply and demand model zones in the AofI, and aggregation of supply model zones into demand model zones elsewhere. This structure may be called an ‘aggregate’ approach and ensure consistency between the costs calculated in the assignment models and those used in the demand models.

3 Geographic Scope and Zoning

3.1 Introduction

3.1.1 This chapter describes the spatial coverage of SEMMMS VDM, summarises the functionality of the model in different areas and presents the zone systems used.

3.2 SEMMMS VDM Geographical Coverage

3.2.1 At an early stage of model development, the SEMMMS modelling team identified an 'Area of Influence' (AofI) of the scheme, within which assignment model validation would be focussed. This is also the area for which base model network coding and density is most detailed, and for which an uncertainty log of future year developments has been assembled (TAG 3.15.5).

3.2.2 The network coding and demand representation is most detailed within AofI and extends, albeit with decreasing levels of detail across the rest of Greater Manchester, Cheshire, Yorkshire, Humberside and the East Midlands. The remainder of Great Britain is represented at a very coarse level of detail.

3.2.3 The AofI was identified using the GM SATURN 2008 networks, which were an earlier version of the SATURN networks covering Greater Manchester than SEMMMS8. Flow difference plots were examined for assignments with and without the SEMMMS scheme. The version of the scheme used in this work was an early version, known as Design Freeze 2. The AofI was defined by the set of links for which the flow difference was +/- 250 pcus.

3.2.4 Although assignment model validation has focused on the AofI of the scheme, supply and demand representation has been extended over a much wider area covering much of the north of England. The primary reason for including full representations of demand and supply processes over such a wide area is to allow for trip redistribution effects when making future year do minimum and scheme forecasts.

3.3 SEMMMS8 Highway Assignment Model Zoning

3.3.1 The zone system developed for use in the SEMMMS8 2009 highway assignment models made extensive use of a zone system developed for the GM SATURN 2005 highway assignment models, used to provide supporting evidence of the 2007 AGMA TIF bid. The GM SATURN 2005 zone system was developed using the following principles:

- Based on local authority areas and, within these, wards to facilitate the compilation of input planning and land-use data.
- Computational constraints restricted the number of zones to around 300 that could be accommodated within the demand model, which was used in association with GM SATURN 2005 assignment models. From the outset of the TIF work it was decided that an appropriate ratio between the number of zones in the demand model and those in the GM SATURN 2005 assignment models would be around 1:3.
- Important traffic generators such as large superstores and hospitals were treated as separate zones.

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3.3.2 For the SEMMMS assignment models, zoning both within and outside Greater Manchester was reviewed. Within Greater Manchester, GM SATURN zones within Stockport, south Manchester and east Trafford were checked, and where necessary, existing zones were disaggregated to better represent key generators and future development sites.

3.3.3 The area surrounding Manchester Airport was looked at in detail. The zoning in the Airport area was reworked based on the location of car parks and pick-up/drop-off areas and with reference to several documents including 'Manchester Airport Masterplan', 'Manchester Airport Ground Transport Strategy' and 'Manchester Airport: the need for land', which outlines Manchester Airport Groups future parking requirements in some detail.

3.3.4 In the GM SATURN model, the zones in Cheshire East were significantly larger than those within Greater Manchester. As the AofI includes part of Cheshire East which is now coded in simulation detail and is in close proximity to the proposed SEMMMS scheme the zoning was reviewed and disaggregated. In particular, the more built up area around Wilmslow, Alderley Edge and Poynton required a more extensive rezoning to better reflect loading points on the network.

3.3.5 The additional zoning within the AofI resulted in a final number of zones in the SEMMMS8 highway assignment models of 1080.

3.4 SEMMMS Variable Demand Model Zoning

3.4.1 As discussed above, the average hour highway and PT assignment models in SEMMMS VDM are used to provide cost skims for input to the demand model with forecast demands from the demand model being reassigned in the assignment models. This requires the zones in the highway and PT supply models to nest within the VDM zones to allow costs from the supply models to be passed to the VDM. However, it does not necessarily require a 1:1 correspondence between zone systems of the assignment models and the demand model. Operating the demand model at a more aggregate level than the assignment models speeds up demand model run time, reduces model data storage requirements and is beneficial when matrices are lumpy, i.e. subject to a degree of sampling bias.

3.4.2 The SEMMMS VDM zone system was developed using the following principles:

- Identical zone system in assignment and demand models across the AofI, which covers parts of Stockport, south Manchester and Cheshire East, allowing for accurate representations within the demand model of travel patterns associated with future developments and their loading points in the assignment models.
- Demand for travel to/from Manchester Airport terminals was aggregated from the eight zones in the assignment models to a single zone in the VDM. Whereas a highly disaggregate zoning system across Manchester Airport improves accuracy of traffic loading in the assignment models, this level of aggregation is not appropriate for demand response modelling. Air travellers' response to changing Airport access costs can be thought of in terms of the whole journey from home to the check-in desk as opposed to a particular car park or public transport terminus. This is particularly important for mode choice so that the total costs of travel by car to the desk can be compared with public transport costs, rather than comparing costs to reach a car park.

For this reason a single demand model zone is used to represent demand to/from Manchester Airport terminals.

- Approximately 3:1 correspondence in zone system between assignment models and demand model across the rest of Greater Manchester to make use of the existing GM-TIF suite of models. The zones in the TIF demand modelling, using GMSPM2, correspond to wards so that planning data could be readily compiled.
- For much of the north of England, which is beyond the AofI full representations of travel demand are included in the demand matrices for these zones although supply coverage becomes progressively simplified further away from the AofI. Simplifying the zoning system for this area between the demand and assignment models significantly speeds up demand model run time and reduces model data storage requirements and can be beneficial if matrices are lumpy.
- Identical zone system in assignment and demand models for the external zones, defined as those for which only fully observed travel demand is included in the demand matrices.

3.4.3 Table 3.1 shows the nesting relationship between the zone systems of the highway assignment models and SEMMMS VDM. In total there are 480 zones in the SEMMMS VDM and 1080 zones in the highway assignment models.

Table 3.1 SEMMMS VDM Zoning and Nesting Relationship with the Zoning of the SEMMMS8 Highway Assignment Models

Model Area	Number of SEMMMS8 Highway Assignment Zones	Number of SEMMMS VDM zones	Ratio
Area of Influence	190	190	1:1
Rest of Greater Manchester and North of England	875	275	3.33:1
External Zones	15	15	1:1
All Zones	**1080**	**480**	**2.30:1**

3.4.4 The zone systems for the highway assignment model and VDM are shown in Figures 3.1 and 3.2.

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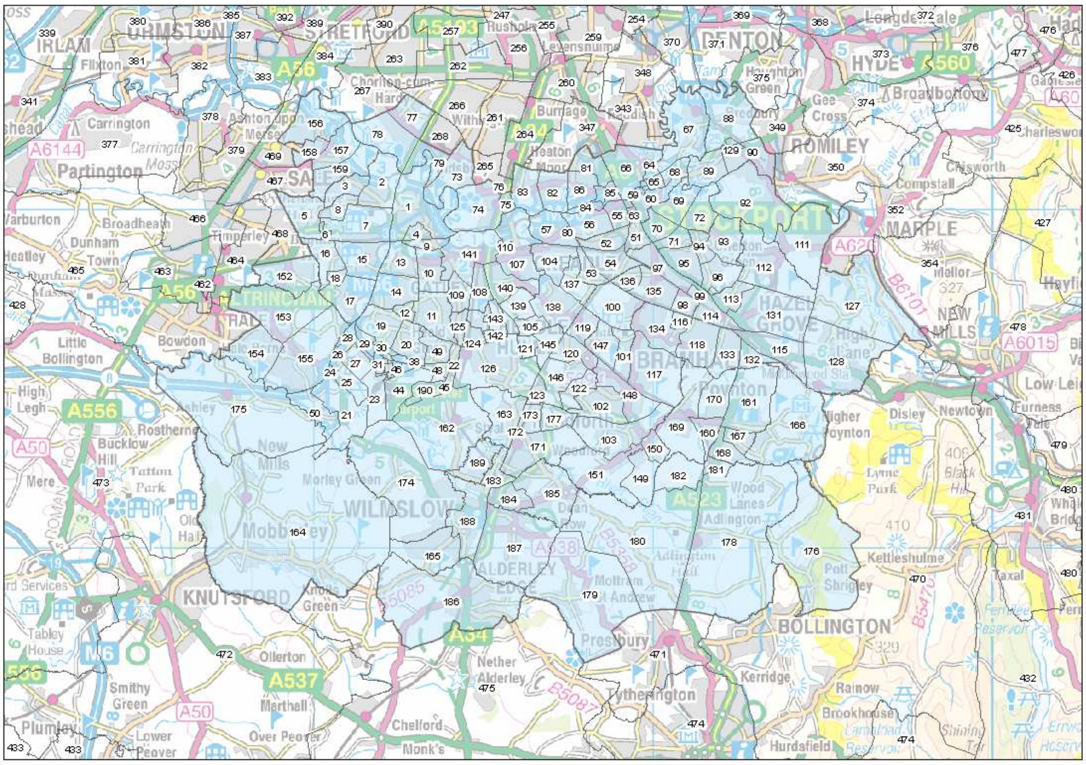

Figure 3.1 SEMMMS VDM demand model zoning and AofI boundary. Zoning is identical within AofI for demand and assignment models

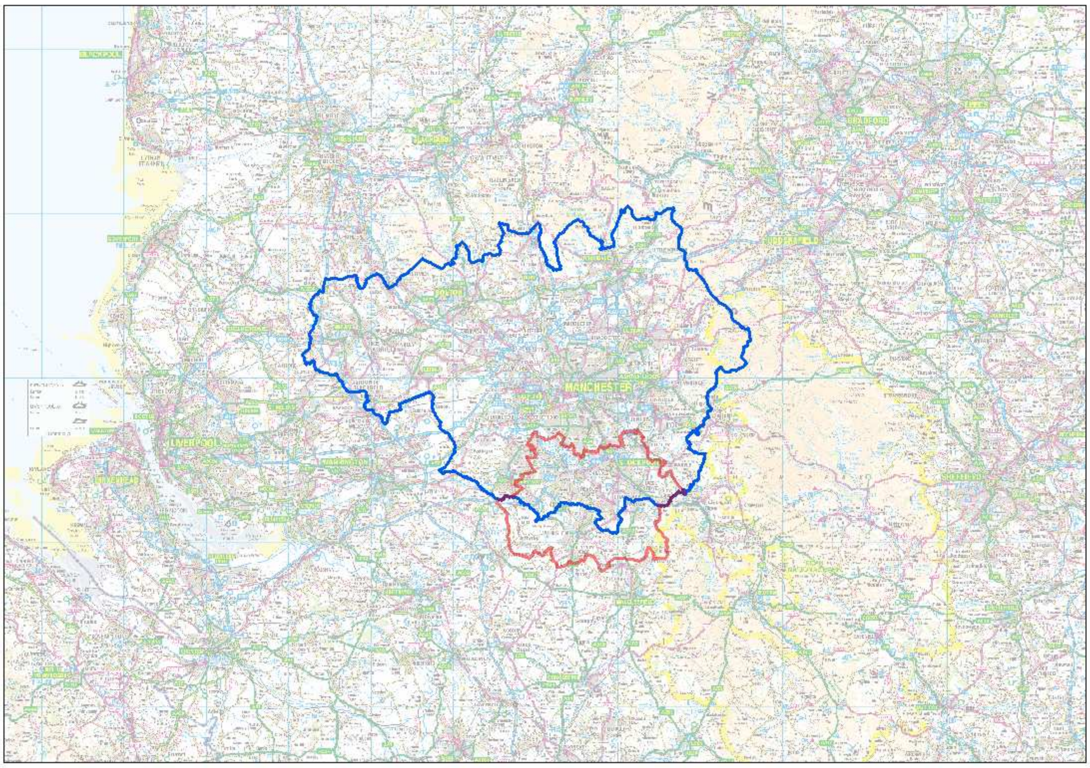

Figure 3.2 SEMMMS VDM demand model zoning (Red line is AofI, Blue line is Greater Manchester)

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SEMMMS8 PT Assignment Model Zoning

3.4.5 The zones in each supply model must nest within the VDM zones to allow costs from the supply models to be passed to the VDM. In theory the PT and highway models could have different zones so long as both systems could be aggregated to the zone system used in VDM. In the Area of Influence the VDM and highway model use the same zone system so that the demand changes which results from cost changes in generalised costs can be most accurately estimated. So:

- the PT model zones must nest within the VDM zones; and
- it has been decided that the same zones will be used in the highway model and VDM in the AofI.

3.4.6 These two factors mean that the PT model zones in the AofI must either be the same as, or nest within, the highway model zones. As the model is not designed to appraise PT schemes it would not be appropriate for the PT model zones to be more detailed than the highway model zones. The SEMMMS8 PT assignment models will therefore have the same 1080 zones as the SEMMMS8 highway assignment models.

3.5 Modelling of Intrazonal Trips

3.5.1 TAG 3.10.2, 1.2.9 states that 'the size of internal zones will need to be carefully considered in relation to intrazonal trips: the larger they are, the larger will be the proportion of trips originating in them which remain intrazonal, i.e. their destination is also within the origin zone itself. It is important to represent the costs of such trips realistically, otherwise there may be biases in the demand model. At the distribution stage it is important to be able to redistribute intrazonal to become interzonals, and interzonals to be come intrazonals, if relative cost change. If the zone sizes are small this is less of a problem, but for large zones it is important that the average intrazonal costs are as realistic as possible'.

3.5.2 We have decided to treat intrazonal trips using four different approaches depending on the relative size of the demand model zones, which is primarily governed by their geographical distance from the AofI of the scheme. The four approaches are:

- Within the AofI (190 zones) where assignment and demand model zones are identical, intrazonal costs are fixed at zero. As discussed later the choice models have an incremental form, are influenced by changes in travel costs rather than the costs per se, and so it does not matter whether the costs are fixed to zero or a different value. This is considered appropriate as zone sizes are small, changes in costs would therefore also be small and SATURN cannot predict intrazonal costs.
- For zones across the rest of Greater Manchester (229 zones) for which assignment and demand model zones are in approximate 3:1 ratio, intrazonal costs in the demand model are derived by demand weighting the relevant inter-zonal costs from the assignment models.
- For external zones only (15 zones) demand observed travelling within AofI and Greater Manchester is included in the demand matrices and therefore no intrazonals are modelled.

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- For all other zones (46 zones) covering the north of England, i.e. those not in the AofI, Greater Manchester or external zones, the network coverage of the assignment models becomes progressively sparser. For this area of the model it is less appropriate to derive average intrazonal costs for use in the demand model from assignment model cost skims. Here, MVA have implemented an alternative method in which intrazonal demand for each of these zones is split into a series of distinct 1km distance bands based on a distribution calibrated for each mode and segment on base travel demand data for zones within AofI and Greater Manchester. These separate bands of intrazonal demand are then included in the distribution model along side the usual interzonal demands. This can be thought of as replacing the single intrazonal movement in the destination choice model with a number of extra zones representing 1 km bands. Costs associated with these intrazonal distance bands are calculated using an average cost per kilometre derived for each mode and segment for zones within AofI and Greater Manchester. These costs are updated for each model run to reflect changes in congestion over time. This approach allows the trip length of intrazonal movements to change in the large zones, resulting in a more realistic destination choice model.

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4 Model Dimensions

4.1 Introduction

4.1.1 This chapter summarises the dimensions defined for SEMMMS VDM, i.e.:

- modes;
- car availability and journey purpose; and
- time periods.

4.2 Modes

4.2.1 As previously discussed the following modes are included in SEMMMS VDM:

- car;
- light goods vehicles – variable demand responses do not apply but included in the highway assignment process as a contributor to congestion and to predict route changes;
- other goods vehicles – treated in the same way as light goods vehicles;
- walk/cycle – as mode shift between slow modes and public transport can occur, to remove the need for a frequency response, and to assist with model calibration; and
- public transport – to allow for the modelling of mode shift over time and in response to the scheme, and to enable the appraisal of impacts of the SEMMMS Relief Road on public transport users.

4.2.2 Park-and-ride journeys are not included in SEMMMS VDM. These represent a small number of trips in the AofI and across Greater Manchester, their inclusion would greatly complicate the model, and no changes to park-and-ride provision are proposed as part of the scheme or in the without scheme scenarios.

4.3 Car Availability and Journey Purpose

4.3.1 Appropriate choice of demand and supply model dimensions is essential to the success of any complex transport model covering a large spatial area. Trade offs need to be made between the segmentation of demand and spatial aggregation; this is critical in creating a model capable of addressing the policy question of interest with constraints in model run time and memory requirements. However, recent development in computer processing power, available RAM, hard disk space and the ability to perform parallel processing across multiple processors means that significantly more segmentation can be accommodated in a model system than was possible just a few years ago.

4.3.2 The model dimensions selected for SEMMMS VDM were chosen in order to satisfy each of the following key requirements of the model, whilst creating a model which had an acceptable run time and call on computing resources (TAG 3.10.2, Table 3):

- TAG compliant demand responses and parameters;

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- model run times of under 36 hours for a single policy forecast in the base year; and
- the number of zones in the SEMMMS8 SATURN models developed by TfGM HFAS would have 1080 zones.

4.3.3 Travel demand in the demand model is grouped into 'segments'. Within each segment demand responds to changes to transport supply in the same manner, i.e. the following characteristics are constant:

- value of time; and
- sensitivity of travel demand responses (time of day, mode and distribution) to changes in travel costs.

4.3.4 Demand is also segmented to facilitate the estimation of the quantity of travel produced by each zone, and how these quantities change over time. The following factors were considered in establishing a preferred set of demand segments:

- data must be available to reliably segment and forecast demand, and to specify values of time and demand response sensitivities;
- the chosen segments should reflect variation of values of time and sensitivity of demand responses to changes in travel costs;
- demand response sensitivity parameters must be available from published sources such as TAG;
- no segment should represent a small proportion of total journeys in both base and future years;
- different levels of segmentation may be appropriate within the demand and the assignment models; and
- model run times must be manageable.

4.3.5 With reference to TAG 3.10.2 Table 3, the minimum model system demand segmentation appropriate for appraisal of the SEMMMS Relief Road would be:

- 2 categories of household car availability – no car and car available;
- 3 trip purposes – commute, business and other; and
- 2 modes – car and public transport.

4.3.6 Thus, in SEMMMS VDM all personal travel demand has been segmented into two household car availability categories:

- no car available households; and
- car available households.

4.3.7 Demand has been further segmented into five purposes (see below) resulting in a total of 10 demand segments:

- home based commute;
- home based employers' business;

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- home based other;
- non home based employer's business; and
- non home based other.

4.3.8 For the purposes of route choice in the assignment models purposes with similar values of time can be combined, and the distinction between home based and non-home based trips is not relevant. Therefore the highway assignment models operate with a more aggregate segmentation than the demand model. The three highway assignment user classes are business, commute and other.

4.3.9 In the public transport assignment model demand for all segments is combined and a single set of routes is chosen using an average value of time. For most public transport corridors within Greater Manchester and the AofI fare differences for bus, Metrolink and rail would not have a strong influence on route choice.

4.4 Time Periods

4.4.1 Four time periods covering 16 hours for a weekday have been included SEMMMS VDM, which allows the impacts of macro time period shifting over time and for the preferred scheme to be assessed given consideration. The time periods are:

AM Peak	0700-0930	2.5 hrs
Inter-peak	0930-1600	6.5 hrs
PM Peak	1600-1900	3.0 hrs
Off-peak	1900-2300	4.0hrs
Total		**16.0 hrs**

4.4.2 These time periods are compatible with the typical 12 hour time period 07:00-19:00 for which observed highway and public transport travel patterns are available.

4.4.3 The SEMMMS VDM time periods fall within those of the validated SEMMMS8 SATURN highway assignment models which are:

AM Peak	0800-0900	peak hour
Inter-peak	0930-1600	average hour (identical to SEMMMS VDM)
PM Peak	1700-1800	peak hour

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4.4.4 Within MVA's demand model home based travel demand is held by 'tour' which is defined as a combination of the from-home and to-home time period. Ten tours were modelled as shown in Table 4.1.

Table 4.1 Definition of Tours

		To Home Period			
		AM Peak	**Inter Peak**	**PM Peak**	**Off Peak**
From Home Period	**AM Peak**	1	2	3	4
	Inter Peak		5	6	7
	PM Peak			8	9
	Off Peak				10

4.4.5 Linking the outward and return elements of home-based journeys to form tours preserves the integrity of the 'travel out, undertake activity, and travel back' sequence whereby response to policies and changes over time is on the basis of the revised total cost of travel for the outward (from home) and the return (to home) journeys combined. Tours modelling enables the effects of transport policies to be represented accurately and consistently across the whole day so that, for example, somebody who travels to work by public transport cannot return by car.

4.4.6 Non-home based movements are represented as one-way trips between origin and destination zones.

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5 Base Year Travel Demand

5.1 Introduction

5.1.1 In this Chapter, we describe the processes that have been undertaken in developing and calibrating the demand matrices required for the SEMMMS VDM system. These are:

- SEMMMS8 highway SATURN assignment peak hour matrices;
- SEMMMS8 highway SATURN assignment average hour matrices;
- SEMMMS8 PT-TRIPS assignment average hour matrices; and
- SEMMMS VDM car, PT and slow mode demand model period matrices.

5.1.2 The car matrices used in the VDM and assignment models have been developed as part of an integrated process, which was intended to ensure consistency. Similarly the public transport matrices in the VDM and PT assignment model were developed using an integrated process. The approach taken to calibrating the supply models in order to maximise consistency was:

- MVA and TfGM HFAS jointly developed prior car matrices for both average and peak hour SATURN models;
- TfGM HFAS collated car and goods vehicle count data for peak and average hours;
- TfGM HFAS calibrated and validated the peak hour highway models;
- MVA took the calibrated highway network, prior average hour matrices and average hour count set from TfGM HFAS and calibrated the AM and PM average hour highway models;
- MVA calculated bus speeds from the calibrated average hour highway assignments for input to the PT-TRIPS models;
- MVA developed the PT prior matrix, collated count data and calibrated and validated the PT models;
- MVA processed the calibrated car and PT matrices for input to the VDM; and
- MVA developed slow mode matrices for input to the VDM.

5.2 SEMMMS8 Highway SATURN Assignment Peak Hour Models

Matrix Building Overview

5.2.1 In 2009, TfGM HFAS was commissioned to build a SATURN model to provide traffic forecasts to inform the development of the business case for the SEMMMS Relief Road. TfGM HFAS's LMVR of February 2012 provides a thorough description of the development and calibration of this model.

5.2.2 The SATURN model represents traffic movements in average weekday by road. Three separate time period models were developed:

- AM Peak 0800-0900 peak hour
- Inter-peak 0930-1600 average hour

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- PM Peak 1700-1800 peak hour

5.2.3 The initial ('prior to matrix estimation') trip matrices constructed for the SEMMMS8 SATURN assignment peak hour models for journeys to and from work were built using information from the 2001 National Census. For other purposes data was taken from roadside interview surveys undertaken for SEMMMS in October 2009 and for Hazel Grove in 2011, supplemented by other RIS undertaken since the completion of the final section of the M60 Manchester Outer Ring Road in October 2000. Other elements of the matrices were taken from synthetic matrices developed by MVA.

5.2.4 The SEMMMS RIS data was collected at 45 sites on screenlines or cordons near the proposed scheme in October 2009. The other roadside interview data was collected in phases over the period June 2001 to April 2004, with interviews being conducted with drivers of private vehicles crossing a series of screenlines and cordons within Greater Manchester.

5.2.5 Trip matrices were built for car, Light Goods Vehicles (LGV) and Other Goods Vehicles (OGV) trips. During matrix construction, observed PA information has been retained for all fully observed car trips, facilitating the construction of assignment demand matrices for the following 12 journey purposes:

- home to work;
- work to home;
- home to employers' business;
- employers' business to home;
- home to education;
- education to home;
- home to shop;
- shop to home;
- home to other;
- other to home;
- non home based employers business; and
- non home based other.

5.2.6 Constructing assignment matrices for these 12 journey purposes in OD format retaining the distinction between from home and to home trips enables matrices in PA format for use in the demand model to be readily derived. However, these 12 journey purposes were ultimately aggregated to much fewer user classes for use in the assignment models. Three user classes have been retained for car (commute, business and other). LGVs and OGVs have separate user classes, giving five user classes in total.

Prior Matrices

5.2.7 During early 2010, TfGM HFAS collated all the available data from the RIS, expanding the journey records to traffic counts and creating observed peak hour travel matrices. These peak hour matrices were converted to average hour matrices using peak hour to average

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hour conversion factors derived from the survey data. These matrices were then required 'infilling' for unobserved movements to provide a full representation of travel movements.

5.2.8 RIS cannot feasibly capture all the movements made across such a wide geographical area and therefore inevitably some movements remain wholly or partially unobserved. The approach to synthesising these movements is documented in Appendix A. A gravity model is one of two methods suggested in DMRB for in-filling trip matrices, the alternative being to in-fill using data from another (fully documented and validated) model. Unobserved movements in SEMMMS8 have been estimated using a gravity model, as there is no other suitable model from which to obtain data. Synthetic demand estimates were produced through use of the following data sources and processes:

- population and land use data from National Statistics website;
- 2001 Census data and travel to work matrices;
- trip rates from GMATS Household Interview;
- gravity models based on distance and calibrated to give mean trip lengths suggested by Transport Statistics Great Britain.

5.2.9 These synthetic matrices were adjusted to ensure that the synthetic trip end estimates (which are consistent with land use data) and trip length distributions were maintained when the demands for observed and unobserved movements were combined.

5.2.10 The processes described above produced average hour demand matrices at the 1080 zone system of SEMMMS8. These matrices were then converted to peak hour demand matrices using average hour to peak hour conversion factors derived from the survey data.

5.2.11 TfGM HFAS created freight matrices using data from the RIS and from the Great Britain Freight Model (GBfMv5), developed by MDS Transmodal.

Matrix Estimation

5.2.12 Initial assignment validation statistics for the peak hour prior matrix assignment indicated that the validation fell short of DMRB guidelines for all time periods, as is commonly found. Matrix estimation was therefore used to enhance the prior trip matrices and improve the match between observed and modelling flows. The following sections describe the outcomes of the final calibration and validation of the peak hour SATURN assignment models.

5.2.13 Traffic counts for both assignment validation and matrix estimation were drawn from TfGM HFAS's count database and from data held by Cheshire East Council and Manchester Airport. The counts considered were mainly post-January 2008, excluding those affected by known 'special' events (e.g., accidents, road works and holidays). The final calibration of the peak hour models selected 916 counts for matrix estimation and validation purposes of which 834 were used in the matrix estimation runs and 82 were used to provided an 'independent' (of ME) check on the calibrated model. The counts were factored to 2009 average October weekday values using locally developed factors.

5.2.14 A number of matrix estimation strategies were explored, using different combinations of counts and parameter values. The final matrix estimation strategy changed the size of the individual vehicle (pcu) matrices by between -4.9% and 2%. Changes of this magnitude were considered acceptable.

Assignment Validation

5.2.15 The SATURN model was validated by comparing modelled link flows and journey times with observed data across the SEMMMS AofI, for the 2009 base year. In total, 59 cordons and screenlines were formed for the link flow validation within the AofI, whilst journey times were compared on 15 (two-way) routes covering key radials and orbitals crossing or parallel to the scheme.

5.2.16 In the AM peak, inter-peak and PM peak hours the percentages of all motorway and local road sites used in calibration which met DMRB validation criteria were 87%, 92% and 88% respectively.

5.2.17 For the independent count set as a whole, the percentage meeting DMRB criteria was 81%, 81% and 82% in the AM peak, inter peak and PM peak hours respectively.

Assignment Validation On Cordons and Screenlines

5.2.18 DMRB suggests that at least 85% of screenlines and cordons should have a GEH value of 4 or less. Considering the 20 calibration cordon and sceenlines in the Area of Influence together, the percentage with GEH values less than 4 is 85% in the AM peak, 80% in the inter peak and 85% in the PM peak.

5.2.19 The above figures show that the model meets DMRB criteria with regard to cordon and screenline validation.

Regression Analysis

5.2.20 TfGM HFAS undertook regression analysis to compare modelled and observed counts. The slopes of the regression lines and the R-squared values are within the guideline ranges specified in the DMRB for all time periods. DMRB indicates that the slope should fall between 0.9 and 1.1 and the R-squared should exceed 0.95.

Journey Time Validation

5.2.21 The primary source of journey time data for this validation was the TrafficMaster database.

5.2.22 The DMRB guideline for journey time validation is that modelled times should be within 15% (or 1 minute if this is higher) of the observed time on more than 85% of routes.

5.2.23 The percentages of routes within 15% of the observed time ranges are 90%, 97% and 93% in the AM peak hour, inter-peak hour and PM peak hour respectively. All three time periods comfortably meet DMRB criteria.

5.3 SEMMMS8 Highway SATURN Assignment Average Hour Models

5.3.1 MVA did not undertake matrix estimation on the average hour prior matrix until after TfGM HFAS had completed validation of the peak hour assignment models. Using final versions of the network, prior matrix and count data ensured maximum consistency was maintained

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between the peak and average hour assignment models. MVA's calibration of the average hour models consequently achieved comparable levels of validation to those TfGM HFAS's achieved for the peak hour models.

5.3.2 Limited origin/destination survey data was available for the off-peak period (1900 – 2300), as no RIS surveys were undertaken after 1900 and HIS does not contain the required origin/destination data. For this reason, the off-peak demand matrix was synthesised using local population and trip rate data, and gravity models in the same way unobserved movements in other time periods.

5.3.3 The average hour SATURN models were validated by comparing modelled link flows with observed data across the SEMMMS AofI, for the 2009 base year. The same 59 cordons and screenlines were used for link flow validation of the average hour models as was used in the validation of the peak hour models. The set of counts used for validation of the average hour models was the same as that used in the final validation of the peak hour models.

5.3.4 In the AM peak, inter-peak and PM peak hours the percentages of all motorway and local road sites used in calibration of the average hour models which met DMRB validation criteria were 91%, 92% and 91% respectively. These results compare favourably with those for the peak hour models (87%, 92% and 88%), reflecting the lower level of traffic in the average hour models than the corresponding peak hour models.

5.3.5 For the independent count set as a whole, the percentage meeting DMRB criteria was 83%, 81% and 77% in the AM, inter peak and PM average hours respectively. Again, these results were comparable with those for the peak hour models (81%, 81% and 82%).

5.4 SEMMMS8 PT-TRIPS Assignment Average Hour Models

5.4.1 The development, calibration and validation of the PT-TRIPS assignment model is documented in MVA's PT model validation report of February 2012. The primary sources of data for the PT model were those used to develop the SPM2-PT model for the TIF study. Passenger interview survey data dates from 2003/4 and provides information on travel into Manchester Regional Centre and other Greater Manchester town centres. Calibration and validation data such as passenger boarding, alighting and on-vehicle counts are of a similar vintage.

5.4.2 Within the AofI MVA refined the SPM2-PT network representation, checked and revised bus and rail service coding, and introduced zoning which matched the SEMMMS8 SATURN model.

5.4.3 MVA re-built the PT demand matrix used for SPM2-PT in a manner that was consistent with the SEMMMS8 highway matrices. As part of the matrix development we ensured that total trip making was consistent with land use data.

Matrix Development

5.4.4 The collection of new origin/destination data was not possible in the time available, nor warranted given the purpose of the model for the appraisal of a road scheme such as the proposed SEMMMS link road. However, MVA did approach Cheshire East Council to ascertain whether additional data were available to enhance the PT model in the AofI. No data were available.

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5.4.5 The matrix development process was therefore based largely on the matrices developed for GMSPM2 and the SPM2-PT model. The following steps were implemented in the development of the SEMMMS8-PT matrices.

Step 1

- The following processes were adapted from those used in the matrix development of SPM2-PT, producing average hour matrices of observed public transport movements for each time period. In summary:
  - GMATS and M60 After origin / destination surveys were used to estimate trips in the "forward" direction (outbound from district centres and northbound across M60 After survey cordons) with expansion factors derived by TfGM HFAS;
  - GMATS and M60 After origin / destination surveys were transposed;
  - movements which were observed on more than one cordon or partially observed were identified using the network model;
  - an initial matrix for movements not captured by GMATS or M60 After origin / destination surveys was developed from available data (eg local origin / destination surveys, CAPRI data, Metrolink Ticket data, Census, etc);
  - matrices from GMATS / M60 data were combined with the infill matrix; and
  - matrix smoothing techniques were applied.
- The matrices represent "true" origin and destination. For example, in the case of a home-to-work trip consisting of a car access leg to a rail station and a public transport leg the origin is recorded as the home zone and the destination recorded as the workplace zone. A separate TRIPS process is implemented prior to assignment which modifies the matrices such that the origin zone in the above example will be re-allocated to the rail station.

Step 2

- synthetic demand matrices for all unobserved movements were created using Census data, observed trips rates and distributions developed from the 2001 Census Journey to Work data; and

Step 3

- the observed and synthetic matrices were combined to produce the initial average hour assignment matrices for input to the calibration of the public transport model.

5.4.6 The AoI trip ends were distributed using the travel to work matrix for all purposes, including for non-commute purposes. This was the most pragmatic solution to deriving robust prior matrices as quickly as possible. For most large buffer zones we wanted PT demand to be distributed mostly within the local area, and gravity models were liable to produce a large number of long distance PT trips (Sheffield to Liverpool etc. which is particularly unsuitable for purposes such as education). This could have been tempered by using a "stronger" parameter in the gravity model but it is not obvious how strong it would need to be or how such a parameter could be calibrated. Using the travel to work matrix therefore appeared more defendable in this scenario, given the purpose of the public transport model for this study and the timescales for model development.

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5.4.7 As the data used to develop the SEMMMS PT model are from 2003/4 and no data were available for the Cheshire East area MVA does not consider the model to be suitable for appraisal of public transport measures. However, as it does provide an estimate of public transport demand MVA consider that it is suitable for use in appraisal of a major road scheme, which is anticipated to have a modest impact on public transport use.

Model Validation

5.4.8 In general it is more difficult to establish patronage estimates by service or link for public transport than for road links, as for the latter continuous automated counts are often available. Therefore TAG Unit 3.11.2 suggests the following validation targets for comparison of modelled and observed passenger flows:

- modelled flows should be within 15% of the observed values on screenlines and cordons; and
- modelled flows should be within 25% of individual counts except where observed flows are less than 150 passengers.

5.4.9 The above targets are for public transport models that would be used in the assessment of public transport schemes. There are no such targets for public transport models used to facilitate a reasonable mode choice in the assessment of a highway scheme, such as the SEMMMS model. The validation within the area of influence was the main focus, with the wider model validation a secondary concern.

5.4.10 A summary of the validation against the GMATS District Centre Cordon counts in the AofI (Altrincham and Stockport) is presented in Table 5.1 to Table 5.2. Overall 73% (27% prior to ME) of links with flows in excess of 150 passengers per hour are replicated to within 25%. All modelled crossing flows are within 15% of observed total screenline crossing flows except for Altrincham outbound AM which is slightly under the target at 21% too low, and Stockport inbound IP which is 20% too low. The absolute numbers of passengers on the Altrincham cordon are low and therefore small differences in absolute numbers result in large percentage changes. This validation is greatly improved compared to the prior ME validation.

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Table 5.1 Bus District Centre Cordons Screenline Summaries (AofI) after Matrix Estimation

	AM			IP			PM		
	Obs	Model	% diff	Obs	Model	% diff	Obs	Model	% diff
Outbound Cordon									
Altrincham	171	136	-21%	330	335	1%	559	468	-16%
Stockport	1757	1490	-15%	1942	1785	-8%	2695	2527	-6%
Inbound Cordon									
Stockport	2365	2018	-15%	1960	1562	-20%	1624	1357	-16%

Table 5.2 Bus Summary District Centre Cordons Individual Counts (AofI) after Matrix Estimation

	AM	IP	PM
Outbound Cordon			
No. links with > 150 pax / hr	6	6	10
No. links with > 150 pax / hr and difference< 25%	4	4	8
% links with > 150 pax / hr and difference <25%	67%	67%	80%
Inbound Cordon			
No. links with > 150 pax / hr	8	7	4
No. links with > 150 pax / hr and difference< 25%	5	5	3
% links with > 150 pax / hr and difference <25%	75%	71%	75%

5.4.11 The rail boarding and alighting validation in the area of influence is presented in Table 5.3. The post matrix estimation validation shows that in general all modelled flows increased, this has resulted in modelled boardings or alightings being within 15% of observed counts in 60% of cases. The summary presented in Table 5.4 shows that for the larger stations with over 150 passengers per hour 60% of modelled flows are within 25% of observed passengers which is a large improvement from the prior to matrix estimation case (10%).

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Table 5.3 Rail Boarding and Alighting Validation (AofI) after Matrix Estimation

	AM			IP		
	Obs	**Model**	**% diff**	**Obs**	**Model**	**% diff**
Boardings						
Airport	315	285	-9%	358	307	-14%
Heald Green	204	193	-5%	56	45	-19%
Bramhall	99	95	-4%	35	30	-13%
Cheadle Hulme	323	323	0%	56	64	14%
Davenport	117	112	-4%	22	22	1%
Woodsmoor	71	61	-14%	18	8	-57%
Stockport	1009	1939	92%	349	681	95%
Total	**2138**	**3009**	**41%**	**894**	**1157**	**29%**
Alightings						
Airport	450	413	-8%	259	214	-17%
Heald Green	46	48	4%	30	29	-5%
Bramhall	8	9	7%	11	9	-19%
Cheadle Hulme	85	119	40%	29	45	57%
Davenport	23	22	-2%	13	13	3%
Woodsmoor	18	16	-11%	9	6	-35%
Stockport	671	1701	154%	257	573	123%
Total	**1301**	**2328**	**79%**	**608**	**889**	**46%**

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5.4.12 The model has considerably more passengers modelled for Stockport than were observed in the surveys. However the counts used are from 2004, and were not uplifted to the model base year of 2009. Published data from the Office of the Rail Regulator indicate that passengers using Stockport increased by over 70% between 2004 and 2009, and therefore the observed data used in the validation may be too low. The ORR data could not be used directly in the validation because it is only available as total annual patronage.

Table 5.4 Rail Boarding and Alighting Summary (AofI) after Matrix Estimation

	AM	IP
Boardings		
No. Stations with boardings > 150 pax / hr	4	2
No. Stations with boardings > 150 pax / hr and difference< 25%	3	1
% Stations with boardings > 150 pax / hr and difference <25%	75%	50%
Alightings		
No. Stations with alighting > 150 pax / hr	2	2
No. Stations with alightings > 150 pax / hr and difference< 25%	1	1
% Stations with alightings > 150 pax / hr and difference <25%	50%	50%

5.4.13 Table 5.5 presents the Metrolink boarding and alighting validation within the area of influence. Prior to ME, at a summary level, the modelled patronage is of the right order of magnitude, however, at a detailed level, some station's modelled patronage are significantly different from observed data. Table 5.6 presents the summary Metrolink validation for stations with larger passenger flows and shows that overall 73% of these have modelled flows within 25% of the observed values showing an improvement over the prior ME case (64%).

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Table 5.5 Metrolink Boarding and Alighting Validation (AofI) after Matrix Estimation

	AM			IP			PM		
	Obs	Model	% diff	Obs	Model	% diff	Obs	Model	% diff
Boardings									
Altrincham	361	348	-4%	208	216	4%	369	352	-5%
Navigation Road	100	188	87%	31	46	50%	34	69	106%
Timperley	251	271	8%	135	74	-45%	131	53	-60%
Brooklands	418	283	-32%	84	54	-36%	91	56	-39%
Sale	104	488	369%	87	199	128%	148	179	21%
Dane Road	38	111	189%	35	32	-9%	77	19	-76%
Totals	**1273**	**1689**	**33%**	**580**	**622**	**7%**	**850**	**727**	**-14%**
Alightings									
Altrincham	487	475	-3%	158	165	5%	306	323	6%
Navigation Road	33	50	49%	23	40	74%	79	144	82%
Timperley	105	40	-62%	115	72	-37%	287	120	-58%
Brooklands	64	26	-59%	60	51	-14%	265	242	-8%
Sale	165	114	-31%	73	144	97%	109	366	237%
Dane Road	95	33	-65%	50	40	-19%	97	68	-30%
Totals	**948**	**737**	**-22%**	**478**	**513**	**7%**	**1142**	**1264**	**11%**

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Table 5.6 Metrolink Boarding and Alighting Summary (AofI) after Matrix Estimation

	AM	IP	PM
Boardings			
No. Stations with boardings > 150 pax / hr	3	1	1
No. Stations with boardings > 150 pax / hr and difference< 25%	2	1	1
% Stations with boardings > 150 pax / hr and difference <25%	67%	100%	100%
Alightings			
No. Stations with alighting > 150 pax / hr	2	1	3
No. Stations with alightings > 150 pax / hr and difference< 25%	1	1	2
% Stations with alightings > 150 pax / hr and difference <25%	50%	100%	67%

5.5 SEMMMS VDM Demand Model Matrices

Forms of Trip Matrices

5.5.1 Travel demand matrices within SEMMMS VDM are held in two alternative ways. The highway and PT assignment models contained within SEMMMS VDM operate with travel demand held in OD format. Each trip in the OD matrix describes a journey from the one-way place the trip commences to the place the trip finishes. These matrices have been constructed primarily from survey data and are held by purpose and time of day of travel.

5.5.2 In the demand model, home based demand is held in tour format (TAG 3.10.2, 1.3), which is an extension of the PA format where there is a further segmentation by from- and return-home time period. Home based trips are trips where the home of the trip maker is either the origin or the destination of the trip. Non home based trips are trips where neither end of the trip is the home of the trip maker. Trip production is defined as the home end of a home based trip or the origin of a non home based trip. Trip attraction is defined as the non home based end of a home based trip or the destination of a non home based trip.

5.5.3 Storing demand in PA or tour format is of primary importance when producing forecasts of future year travel patterns as changes in residential and employment locations are likely to be very different. Residential property is by definition the key driver of trip productions where as employment, educational establishments, retail floorspace, etc are the key drivers of trip attractions. Particular attention has been given within SEMMMS VDM to the modelling of Manchester Airport, which is the single most significant attractor within the AofI of the SEMMMS scheme.

5.5.4 Using demand matrices held in tour format within the demand model whilst operating with demand held in OD format within the assignment models necessitates making a conversion between tour and OD formats. This conversion is undertaken after the demand model has been run and before assignment in each demand/supply loop of the SEMMMS VDM.

5.5.5 Use of the tour format simplifies the conversion of tour matrices to OD. The tour is broken into its constituent from-home and to-home trips, the to-home trip transposed and the trips combined into the respective OD trip time period matrices. For car demand a conversion from number of persons to number of vehicles is made using vehicle occupancy data derived from TAG 3.5.6.

5.5.6 In contrast, demand models which use PA rather than tour matrices require PA to OD conversion factors to be defined disaggregated by time of day and trip purpose. These factors are typically assumed to remain unchanged over time, which is unlikely to be the case in reality (TAG 3.10.2, 1.3.4).

5.5.7 Following assignments, OD trip costs are used to create tour costs for use in the demand model. This simply entails summing the cost of a trip from P-to-A in the outbound time period and A-to-P in the return-home time period.

Development of Tour Matrices

5.5.8 The starting point for creating tour matrices for the VDM were the SATURN highway and PT-TRIPS public transport validated average hour assignment matrices. These were disaggregated into the required purpose, household car availability and tour categories.

5.5.9 Conversion to tour requires the calculation of return home probability (RHP) and leave home probability (LHP) factors. RHPs are the proportions of trips which leave home in each time period that return in another. An example of RHP factors is presented in Table 5.1. Note that each row does not necessarily sum to 100% as trips may return after the off-peak period or on the following day. These trips were relatively few and were discarded.

Table 5.7 Example of Return Home Probabilities for a commute Segment (NB 54% of demand leaving home in the PM peak is assumed to return home the next day)

		To Home Period			
		AM Peak	Inter-peak	PM Peak	Off-peak
From Home Period	AM Peak	1%	15%	78%	6%
	Inter-peak		11%	40%	38%
	PM Peak			10%	36%
	Off-peak				10%

5.5.10 RHPs are applied to the calibrated from-home matrices and LHP to the to-home matrices in order to estimate tour demand. This gives two different estimates of each tour matrix, each of which will have been adjusted during matrix estimation. As neither estimate is definitive the estimates are combined after the application of factors. For example the AM out/PM return tour matrix could be formed from 50% of the tour matrix estimated from the AM from-home OD matrix, and 50% of the PM to-home matrix, The factors are calculated so that when the resulting tour matrices are translated back to OD format the calibrated OD matrices are recovered.

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5.5.11 RHP and LHP factors were calculated using data from the GMATS HIS data for the GM-TIF models using the process summarised below:

- HIS trip records were expanded using factors supplied by TfGM HFAS;
- home-based trips were grouped into sets of trips in chronological order between visits to home for each respondent;
- from-home and to-home trips were separated;
- corresponding from-home and to-home trips with the same attraction were matched;
- time periods were assigned to each record;
- trips were summed over O-D retaining segmentation by mode, purpose, car availability, forward time period, and return time period; and
- RHP and LHP factors were calculated for each combination of mode, purpose, car availability, forward period, and return period.

Segmentation of Demand by Household Car Availability

5.5.12 Demand matrices were segmented by household car availability for all purposes. Household car availability splitting factors were derived using data from GMATS.

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6 Demand Model Processes

6.1 Introduction

6.1.1 This chapter discusses the functionality of the demand model in more detail. The demand model component of SEMMMS VDM implements a hierarchical logit formulation, providing a choice set of travel responses containing the alternatives of destination, mode and macro time of day. The demand model utilises MVA's bespoke demand model software, which is written in the C# programming language interfacing with an SQL Server database.

6.1.2 As shown in Figure 2.2 the demand model is integrated with SATURN and PT-TRIPS assignment models. Following each run of the demand model the reference case SATURN and PT-demand matrices are adjusted, reassigned and cost skims are fed back to the next run of the demand model. This process iterates until supply and demand are in equilibrium.

6.1.3 This chapter is structured under the following headings:

- input demand matrices and the role of the VDM;
- demand model functional form;
- generalised costs; and
- supply and demand model interface.

6.2 Input Demand Matrices and the Role of the VDM

6.2.1 The demand matrices input to SEMMMS VDM represent a 'reference case' future year forecast reflecting changes in zonal demographics such as population, jobs and car availability. These reference case forecasts reflect a situation where the generalised costs of travel are identical to the generalised costs in the base year.

6.2.2 Demand for new developments is super-imposed on the reference case matrix. Development related demand is estimated by applying trip rates to estimates of population or floorspace and using either a gravity model to distribute trips or copying a distribution from nearby zones with similar land used.

6.2.3 SEMMMS VDM then modifies these input matrices to account for changes in generalised cost relative to the base which will result from changes to the components of generalised cost (see Table 6.1 later), values of time and vehicle operating costs.

6.2.4 Base year generalised costs are calculated by running the VDM in 'base model' mode which simply produces a reference set of costs for travel movements that are in equilibrium without applying any demand changes.

6.3 Demand Model Functional Form

Hierarchical Logit Formulation

6.3.1 The demand model component of SEMMMS VDM represents the demand for travel using a mathematical mechanism which reflects how demand will change as costs change. The

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mathematical mechanism used in SEMMMS VDM is a hierarchical logit formulation. The logit mechanism is applied in an incremental form, which predicts changes in demand (relative to a base case) as a function of changes in travel costs. This is the Department's preference for road scheme appraisal (TAG 3.10.3, 1.5.24). However, an issue occurs with this approach in forecasting when a zone is redeveloped or has no trips it in the base situation. For new developments travel patterns are synthesised exogenously in the trip generation stage.

6.3.2 The travel responses included in the demand model are:

- macro time of day of travel;
- which travel mode to use (car, public transport or walk/cycle); and
- where to travel to (distribution).

6.3.3 The relative sensitivity of these responses to changes in generalised cost is as recommended in TAG with destination choice is more sensitive than mode choice, which in turn is more sensitive than macro time of day choice (see Figure 6.1).

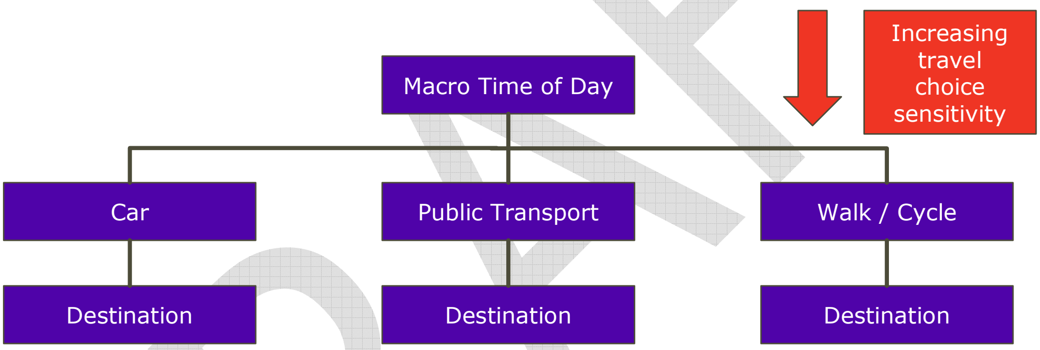

Figure 6.1 Demand model travel choice hierarchy

Mathematical Form

6.3.4 Appendix 4 of TAG 3.10.3 describes how the incremental hierarchical logit model can be specified. The standard incremental multinomial logit model, implemented in SEMMMS VDM, is given by the following equation:

$$p_i = \frac{p_i^0 \exp(\theta \Delta U_i)}{\sum_j p_j^0 \exp(\theta \Delta U_j)}$$

- p_i is the forecast probability of choosing alternative I;
- p_i^0 is the reference case probability of choosing alternative i (calculated from the input reference demand);
- θ is the scaling parameter (θ = 1 for the most sensitive level of the hierarchy and 0 ≤ θ ≤ 1 for less sensitive choices); and
- ΔU_i is the change in the utility of alternative i.

6.3.5 For the choice at the most sensitive level of the hierarchy the simplest form for a change in utility is given by:

$$\Delta U_i = \lambda(C_i - C_i^0)$$

- C_i is the forecast generalised cost, skimmed from the latest assignment;
- C_i^0 is the reference generalised cost; and
- λ is the spread or dispersion parameter; it should be negative.

6.3.6 For the choices above the most sensitive level of the hierarchy the change in utility is the composite change over the alternative in the level below calculated using the logsum formula:

$$\Delta U^* = Ln \sum_i p_i^0 \exp(\Delta U_i)$$

Double Constraint of Demand

6.3.7 As recommended in TAG Unit 3.10.3 (1.7.2), the destination choice model for travel to work demand is doubly-constrained, whereas demand for other purposes is only singly (production-end) constrained. It is common to use doubly-constrained models for forecasting commuting, so that each zone attracts and generates a fixed total of work trip ends, and singly-constrained models for other purposes, where only the total number of trips originating in each zone is fixed, using the techniques described below.

Goods Vehicles Demand Responses

6.3.8 Changes in good vehicle demand are input to the model as exogenous forecasts such as the National Transport Model. No demand responses are modelled in SEMMMS VDM for goods vehicles, although there is route choice within the SEMMMS8 SATURN model.

Manchester Airport

6.3.9 Demand responses for trips associated with Manchester Airport have been restricted to mode choice only. Changes in generalised costs of travel are unlikely to strongly affect the choice of airport or the time of day of travel to the airport. These choices will be much more strongly determined by flight schedules. In particular it was necessary to avoid re-distributing air passenger journeys to the airport to non-airport zones.

6.3.10 Restricting demand responses for Airport journeys has been achieved by doubling the number of demand segments, and allocating all trips to or from the airport to the additional demand segments.

6.4 Generalised Costs

Generalised Cost Formulation

6.4.1 Generalised costs used in the demand model are calculated by summing the monetary cost and time elements (Table 6.1) that are extracted from the assignment models. OD matrices

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of cost elements are calculated in the supply models and converted to 2-way tour matrices for use in the demand model.

Table 6.1 Components of Generalised Cost

Car	Public Transport	Walk / Cycle
Time	Walk time	Time
Fuel cost (all segments)	Wait time	
Non-fuel operating cost (employers' business only)	In vehicle time	
Road user charges	Fare	
	Boarding and interchange penalty	

6.4.2 Monetary values of cost are converted to units of time using values of time, which are input to the demand model disaggregated by demand segment. Values of time for use in SEMMMS VDM demand segments have been derived from values given in TAG Unit 3.5.6. Walk and wait time factors, and boarding and interchange penalties were calibrated as part of the PT model development and are documented in its validation report.

6.4.3 SEMMMS VDM provides a facility to modify the generalised costs to reflect user perceptions that are not directly related to measurable time and money costs of travel, as calculated in the assignment models. This facility has proved useful in previous applications as a means to reflect improvements to interchanges, public transport vehicle quality and cleanliness, passenger information, marketing, etc. These adjustments can be varied by zone pair, time period and mode and have been used to reflect improvements to Altrincham Interchange within future year forecasts by reducing generalised cost for all OD pairs which would use the interchange.

Values of Time

6.4.4 Values of time for inclusion in the demand model have been derived using data from TAG 3.5.6. Values of time for each demand segment used for car, public transport and slow mode travel are shown in Table 6.2.

Table 6.2 Values of Time by Demand Segment (£/hr, 2009 Values and 2002 Prices)

Purpose	Value of Time (£/hr)
Commute	5.24
Business	28.07
Other	4.64

6.4.5 Values of time used for goods vehicles are shown in Table 6.3 Freight Values of Time (£/hr, 2009 Values and 2002 Prices).

Table 6.3 Freight Values of Time (£/hr, 2009 Values and 2002 Prices)

Freight Category	Value of Time (£/hr)
Light goods	8.38
Other goods	8.84

Vehicle Operating Costs

6.4.6 Vehicle operating costs for input to the demand and assignment models were derived using data from TAG 3.5.6. Base year values were input to the models in 2009 values and 2002 prices.

Cost Damping

6.4.7 TAG 3.10.2, 1.11.1 references evidence from Daly (2008) that suggests the sensitivity of demand responses to changes in generalised cost reduces with increasing trip length. We have included a representation of this variation to ensure that SEMMMS VDM meets the requirements of the realism tests as specified in TAG 3.10.4. By way of example, it seems unreasonable that a cost change of 3 minutes should have similar demand effects for a journey of 30km as for a journey of 150km.

6.4.8 The form of cost damping implemented in SEMMMS VDM is damping of generalised cost as a function of distance. It has been applied to all person demand responses, identically for different modes and purposes. Therefore, factors are applied to damp cost differences in the model depending on their trip length. These factors are simply applied to the calculated costs differences (forecast – base). MVA has implemented the damping function given in TAG 3.10.2, 1.11.5 and given below.

$$g' = (d/k)^{-\alpha}.(t + c/v)$$

where

t, c are the trip time and money cost, respectively;

v is the value of time;

(t+c/v) is the generalised cost;

g′ is the damped generalised cost;

d is the trip length; and

α, κ are parameters that need to be calibrated.

6.4.9 SEMMMS VDM applies a minimum distance cut-off, below which the cost damping does not apply. The purpose of such a cut-off is to prevent short-distance trips, particularly intrazonal, becoming unduly sensitive to cost changes.

6.4.10 The parameter values given in TAG 3.10.2, 1.11.10 of α=0.5, κ=30 were shown to be appropriate for use in SEMMMS VDM as part of the calibration process described in the following chapter.

6.5 Supply and Demand Model Interface

6.5.1 As discussed in the previous section generalised costs extracted from the supply models are input to the demand model. In the opposite direction, changes in average hour travel demand predicted by the demand model are applied to the input demand matrices.

Applying Demand Changes

6.5.2 Forecasts of highway and PT assignment OD trip demand are derived by making adjustments to the validated base year assignment matrices, reflecting differences between the forecast demand model tout matrices and the equivalent base demand model tour matrices. In the language of TAG 3.10.2, 1.5.5 this model system is of Type 4, a ‘pivot’ and ‘adjusted’ model system (see Figure 6.2).

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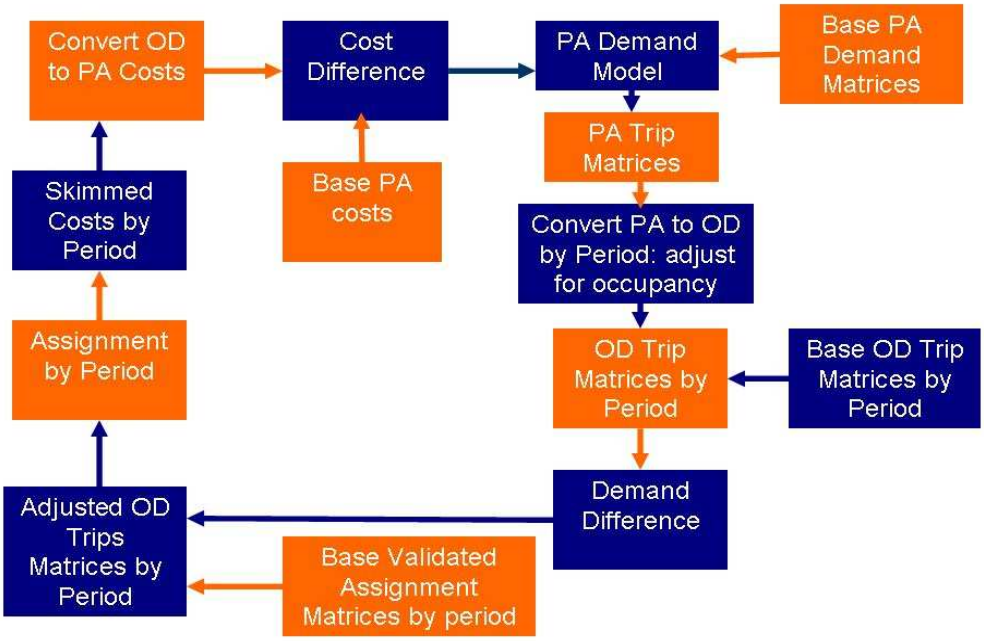

Figure 6.2 SEMMMS VDM is of Type 4, 'pivot' and 'adjusted' model System

6.5.3 Adjustments to the validated base year assignment matrices could be made through either an additive or proportional approach (TAG 3.10.2, 1.5.4). However, as recognised by TAG, problems can occur with both of these methods for certain parts of the matrix in situations where there is insufficient consistency between the demand model and the assignment matrices. This scenario is most apparent for new developments for which no representative travel patterns exist in the base matrices.

6.5.4 The adjustment method used in SEMMMS VDM is primarily additive, although further growth factor constraints are applied to the row and column trip ends, and finally to the whole matrix total. Applying a fundamentally additive approach enables travel patterns associated with new developments, which are explicitly input to the demand model matrices during the trip generation stage, to be properly reflected in the assignment matrices.

Bus Speeds

6.5.5 The model system also has interfaces between the SATURN and PT-TRIPS models to pass highway speeds to the public transport model so that bus speeds vary with the highway speed, and to allow bus flows to impact on highway network performance. Link speeds in the time period PT-TRIPS public transport models are updated with those calculated in the respective SATURN highway assignments each time the supply components of the system are run.

6.6 Iteration and Convergence

6.6.1 SEMMMS VDM runs iteratively until it reaches equilibrium between the supply and demand components. After each run of the demand model, demand adjustment factors are

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calculated and applied to the SATURN highway and PT-TRIPS public transport base year demand matrices for reassignment.

6.6.2 Cost skims taken from the SATURN highway and PT-TRIPS public transport models are input to the demand model. The method of successive averages (MSA) is used to combine costs from successive demand/supply loops in order to hasten convergence (TAG 3.10.4, 1.4.5). MSA is formulated as follows:

$$C_n' = \frac{1}{n} C_n + (1 - \frac{1}{n}) C_{n-1}$$

where:

n is the loop number

C_n' is the average cost

C_n is the cost from the supply model for loop n

C_{n-1} is the cost from the supply model for loop n-1

6.6.3 The process ends when the convergence criteria are achieved. The convergence criteria are set with reference to the DfT %Gap statistic (TAG 3.10.4, 1.5), which states that a value of 0.2% should be achieved. %Gap is defined as follows:

$$\%GAP = \frac{\sum_{ijctm} C(X_{ijctm}) \left| D(C(X_{ijctm}) - X_{ijctm} \right|}{\sum_{ijctm} C(X_{ijctm}) X_{ijctm}} \times 100,$$

where:

the index combination *ijctm* denotes a particular combination of origin zone *i*, destination zone *j*, demand segment *c*, time period *t* and mode *m*;

X_{ijctm} is the previous outer loop's set of trip matrices, in OD format, that are used by the assignment models;

$C(X_{ijctm})$ is a matrix of generalised costs derived from an assignment of the demand produced by the previous loop; and

$D(C(X_{ijctm}))$ is the current trip matrix, which results from running the demand model with the updated costs.

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7 Demand Model Calibration

7.1 Introduction

7.1.1 In Chapter 6 we described the key processes contained within the SEMMMS VDM demand model. This chapter documents the model parameters that have been applied, how those parameters have been selected and how the fitness-for-purpose of the model has been established. The chapter is structured under the following headings:

- model calibration using illustrative parameters; and
- realism testing.

7.2 Model Calibration Using Illustrative Parameters

7.2.1 TAG 3.10.3, 1.10.1 suggests three alternative approaches to choosing the parameter values that control the travel responses:

- use local data to calibrate parameter values;
- use parameter values obtained from other local models; or
- use 'illustrative' parameter values based on general modelling experience.

7.2.2 MVA ruled out using local data to calibrate parameter values for SEMMMS VDM due to timescale and cost. No other model was considered sufficiently similar in geographical coverage, demand segmentation and/or functionality to permit parameter values to be transferred to SEMMMS VDM. The median 'illustrative' parameters provided in TAG 3.10.4 were therefore taken as the starting point for the demand model calibration.

7.2.3 TAG 3.10.3, 1.11.4 states that 'whatever [parameter] values are selected, whether from local knowledge or based on the illustrative values, it is essential to conduct 'realism tests' … to ensure that the actual behaviour of the model against variation in travel times and costs accords with experience'. In our view it is vital that a model achieves an appropriate level of model responsiveness, described in terms of the outturn elasticity values of the realism tests.

7.2.4 A check has been made that the incremental model does indeed forecast no change in demand from the base for no change in costs.

TAG Illustrative Spread Parameters

7.2.5 A set of illustrative spread parameters are given in TAG for use with the utility function presented in Chapter 4 on the basis that destination choice is more sensitive than mode for all travel purposes (TAG 3.10.3, 1.11). These parameters are reproduced in Table 7.1.

Table 7.1 TAG Destination Choice Sensitivity Parameters

Trip Purpose & Mode	Minimum	Median	Maximum
Car			
Home-Based Work	-0.054	-0.065	-0.113
Home-Based Employers Business	-0.038	-0.067	-0.106
Home-Based Other	-0.074	-0.090	-0.160
Non-Home Based Employers Business	-0.069	-0.081	-0.107
Non-Home Based Other	-0.073	-0.077	-0.105
Public Transport			
Home-Based Work	-0.023	-0.033	-0.043
Home-Based Employers Business	-0.030	-0.036	-0.044
Home-Based Other	-0.033	-0.036	-0.062
Non-Home Based Employers Business	-0.038	-0.042	-0.045
Non-Home Based Other	-0.032	-0.033	-0.035

TAG Illustrative Scaling Parameters

7.2.6 Similarly, TAG provides illustrative scaling parameters which describe the sensitivity of main mode choice relative to destination choice. These are shown in Table 7.2. Consistent with destination choice being more sensitive than main mode choice, the main mode choice scaling parameters are all less than or equal to one.

Table 7.2 TAG Main Mode Scaling Parameters

Trip Purpose	Minimum	Median	Maximum
Home-Based Work	0.50	0.68	0.83
Home-Based Employers Business	0.26	0.45	0.65
Home-Based Other	0.27	0.53	1.00
Non-Home Based Employers Business	0.73	0.73	0.73
Non-Home Based Other	0.62	0.81	1.00

7.2.7 TAG does not explicitly provide parameters for use with macro time of day response. However, TAG 3.10.3, 1.11.17 suggests that macro time of day response should be about the same as main mode choice. We have therefore included macro time of day response with a scaling parameter of 1.

7.3 Realism Testing

7.3.1 Model calibration has concentrated on calibrating the response to three tests:

- increasing fuel costs by10%;
- increasing PT fare by 10%; and
- increasing car journey time by 10%.

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7.3.2 The outturn elasticity values that TAG suggests should be achieved from these tests are fuel price elasticity between -0.25 and -0.35 (car-kms with respect to fuel price), with commute trips being less elastic than the more discretional purposes. The suggested medium term PT fare elasticity value should be in the range -0.2 to -0.9 (PT trips with respect to fare). Elasticities have been measured using an arc formulation as recommended in TAG Unit 3.10.4:

$$e = \frac{\ln(d^1 / d^0)}{\ln(c^1 / c^0)}$$

where d^1 and d^0 represent demand in base and test scenarios, and c^1 and c^0 represent corresponding costs.

7.3.3 For SEMMMS7C, calibration was undertaken in a structured fashion as follows:

- Test 1. Realism tests were run using the illustrative parameters, but without iterating the demand model. As recommended in TAG Distance Based Cost Damping (DBCD) was not used in Test 1. This gave a quick indication of how closely the model, with the illustrative parameters, would reproduce the target elasticities. The impact of converging the model system on parameters was established in a later step.
- Test 2. DBCD was introduced.
- Test 3. The VDM was run to convergence.
- Test 4. Adjustments were made to the parameters, within bounds recommended by TAG, in order to reproduce the target elasticities.

7.3.4 Appendix B presents the parameters and the elasticity values resulting from each of these tests as they were run for SEMMMS7C. For SEMMMS8, we have repeated Test 4, the results of which are presented in the following section.

Test 4. Final Results of Demand Model Calibration for SEMMMS8

7.3.5 For SEMMMS8, adjustments were made to some of the demand model parameters to improve the relativity of outturn elasticity values by purpose. To this end, the car commute destination parameter was reduced whilst the car home based other and non home based other destination parameters were increased. This was done to ensure the fuel price elasticity value for commute was less than those of the more discretionary purposes. The commute parameter was reduced to its minimum values (17% less than the median values) and the home based other and non home based other parameters were increased by 25%, the maximum relative change from the median value readily permitted by TAG (TAG 3.10.4, 1.7.11).

7.3.6 Similarly the PT destination parameter for home based other was increased by 25% in order to make the PT fare elasticity value for home based other more elastic than that for commute.

7.3.7 The final SEMMMS7C parameters were input to the SEMMMS8 demand model, and are shown in Table 7.3. The outturn fuel price and PT fare elasticity values are shown in Table 7.4.

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7.3.8 **The final fuel price elasticity value aggregate over all purposes for the whole model was -0.28 (-0.3 for SEMMMS7C) and PT fare elasticity was -0.40 (-0.44 for SEMMMS7C).**

Table 7.3 Final parameters input to SEMMMS VDM demand model (red values have been adjusted away from the median TAG values)

Purpose	Median Logit Model Parameters				
	Lambda Values (λ)			Scaling Parameters (θ)	
	Car Dest'n	PT Dest'n	Walk/cycle Destination	Mode	Macro Time
HB Commute	-0.0270	-0.0165	-0.0325	0.68	1
HB Employers Business	-0.0335	-0.0180	-0.0335	0.45	1
HB Other	-0.0563	-0.0225	-0.0450	0.53	1
NHB Employers Business	-0.0810	-0.0420	-0.0810	0.73	1
NHB Other	-0.0963	-0.0330	-0.0770	0.81	1

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Table 7.4 Test 4 Fuel Price and PT Fare Realism Test Results

	Test 4: Final parameters, cost damping (α=0.5, k=30,d´=30km), converged demand model			
	Car Fuel Vehicle Km Elasticity Values		PT Fare Trip Elasticity Values	
	To/from/ within AofI	Whole Model	To/from/ within AofI	Whole Model
HB Commute	-0.34	-0.27	-0.46	-0.36
HB Employers Business	0.00	0.05	-0.20	-0.16
HB Other	-0.44	-0.32	-0.59	-0.41
NHB Employers Business	0.00	0.05	-0.30	-0.29
NHB Other	-0.31	-0.31	-0.59	-0.50
All Purposes	**-0.34**	**-0.28**	**-0.53**	**-0.40**
AM	-0.30	-0.23	-0.53	-0.39
IP	-0.31	-0.27	-0.53	-0.40
PM	-0.32	-0.25	-0.52	-0.40
OP	-0.46	-0.37	-0.52	-0.49

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7.3.9 The outturn fuel price and PT fare elasticity values for SEMMMS8 are almost identical to those from SEMMMS7C, as reported in Appendix B.

7.3.10 As anticipated elasticity values for both fuel price and PT fare are higher in the off-peak than other time periods. However, one might expect lower elasticity values in the peaks than the inter-peak. In fact, in SEMMMS VDM there is little difference between the elasticity values in the AM, IP and PM time periods.

7.3.11 Fuel elasticities for employers business trips are slightly positive. This is because the increase in fuel cost has a greater deterrent effect for the commute and other purposes, which have lower values of time than employers business, and the resulting reduction in congestion counteracts the fuel cost rise for business travellers.

7.3.12 Table 7.5 shows the PT fare elasticity values disaggregated by household car availability category. TAG 3.10.4, 1.6.24 suggests elasticity values for car available segments might be expected to be greater than those of non car available segments, since the former have greater choice than the latter, and this is the case for SEMMMS VDM.

Table 7.5 PT Fare Elasticity

	To/from/within AofI	Whole Model
No car available	-0.47	-0.35
Car available	-0.57	-0.45
All categories	**-0.53**	**-0.40**

Car Journey Time Elasticity

7.3.13 TAG 3.10.4, 1.6.27 requires car journey time elasticity values to be calculated based on the change in car trips with respect to a 10% change in journey time. We have calculated car journey time elasticity values by inputting a factored matrix of car travel times, skimmed from the base model, to a single run of the demand model.

7.3.14 As anticipated, journey time elasticity values, shown in Table 7.6, vary much more than the fuel cost elasticity values (TAG 3.10.4, 1.6.30). However, values are not disproportionately high and all are less than -1.0.

Table 7.6 Test 4 Car Journey Time Realism Test Results

	Median TAG parameters, cost damping (α=0.5, k=30,d´=30km) , converged demand model	
	Car Fuel Vehicle Km Elasticity Values	
	To/from/within AofI	Whole Model
HB Commute	-0.29	-0.15
HB Employers Business	-0.13	-0.10
HB Other	-0.32	-0.22
NHB Employers Business	-0.12	-0.12
NHB Other	-0.21	-0.20
All Purposes	**-0.29**	**-0.20**
AM	-0.30	-0.22
IP	-0.26	-0.23
PM	-0.31	-0.21
OP	-0.30	-0.11

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Network Based Elasticity Values

7.3.15 TAG 3.10.4, 1.6.12 requires car fuel price elasticity values to be calculated on a network basis, as well as on an OD basis for which results are presented above. TAG suggests that these elasticity value calculations are likely to underestimate the fuel cost elasticity if the change in car vehicle kilometres includes fixed elements.

7.3.16 However, the reverse is the case for SEMMMS VDM. The demand model contains a mechanism whereby cost changes impact on the intrazonal demands of the large buffer zones. Demand changes for intrazonals are by definition relatively short in length. As this demand is not reassigned to the network the overall network based elasticity values are slightly higher than the elasticity values for the whole model calculated on an OD basis.

7.3.17 Whereas the fuel price elasticity value for the whole model calculated on an OD basis is -0.28, the values calculated on a network basis are -0.3, -0.35 and -0.31 for the AM, IP and PM assignment models respectively.

Table.7.7 Test 4 Network Based Fuel Price Realism Test Results

Time Period	Car Fuel Vehicle Km Elasticity Values
AM	-0.30
IP	-0.35
PM	-0.31

7.4 Summary

7.4.1 In this Chapter we have described the processes of calibration and validation of the demand model. The approach taken to calibration of the demand model was to import parameters from the illustrative values presented in TAG and adjust them to produce reasonable results in the realism tests. This approach produced a reasonable model, with overall elasticity values within the target range for both the realism tests.

7.4.2 With the parameters taken from within the ranges of the illustrative values and a cost damping curve employed, the elasticity of car vehicle kilometres to fuel price was -0.28, within the target range of -0.25 to -0.35. The public transport fare trip elasticity of -0.40 was within the target range of -0.2 to -0.9. Appropriate elasticity values disaggregated by purpose and time of day have been achieved. The car journey time trip elasticity of -0.20 was much less than the maximum allowable value of -2.0.

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Appendix A – Synthetic Highway Demand Matrices

Technical Note

Project Title:	SEMMMS A6 to Manchester Airport Relief Road
MVA Project Number:	C39358
Subject:	Highway Demand Matrices
Note Number:	13 Version: 3
Author(s):	Pete Kidd
Reviewer(s):	Nick Benbow
Date:	24 February 2012

1 Introduction

1.1 MVA Consultancy has been working between February 2010 and February 2012 to construct a transport model system fit for the purpose of providing modelling inputs for a Major Scheme Business Case (MSBC) of the SEMMMS Relief Road to the Department for Transport (DfT). This system is known as SEMMMS Variable Demand Model (VDM) and combines MVA's bespoke demand model with validated SATURN highway and PT-TRIPS public transport assignment models. SEMMMS VDM includes highway and PT assignment models representing average hours for morning, inter and evening peak time periods.

1.2 In parallel, TfGM HFAS was commissioned to produce validated SATURN peak hour assignment models for a morning and evening peak hour, as well as an average inter-peak hour.

1.3 This note describes the processes used in creating matrices for the three average and two peak hour highway assignment models, which involved combining survey data from a number of Roadside Interview Survey (RIS) programmes together with synthetic estimates of demand.

1.4 Matrix estimation was applied to these matrices during calibration and validation of the assignment models, as discussed in the highway model validation report.

1.5 This note has the following structure:

- background;
- summary of approach;
- roadside interview surveys;
- trip ends;
- distribution model forms;
- calibration and forecasting procedures;
- matrix analyses; and
- appendix A segmentation definitions.

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2 Background

2.1 Compliance with DfT's Transport Analysis Guidance (TAG) for the appraisal of the SEMMMS road scheme requires that the VDM contains a distribution model. This in turn requires demand representations to be included across a wide geographical area so that the total pool of travel demand which does or may impinge on the Area of Interest (AofI)[1] is included in the model. To this end, full demand representations have been included in the model for zones covering much of the north and midlands of England. Note that for the 15 external zones (e.g. Scotland and South East of England) only demand observed entering the study area will be included in the model.

2.2 RIS cannot feasibly capture all the movements made across such a wide geographical area and therefore inevitably some movements remain wholly or partially unobserved. A gravity model is one of two methods suggested in DMRB for in-filling trip matrices, the alternative being to in-fill using data from another (fully documented and validated) model. Unobserved movements in SEMMMS8 have been estimated using a gravity model, as there is no other suitable model from which to obtain data.

2.3 MVA have used gravity models to in-fill demands for non-commute purposes, and TfGM HFAS have used data from the 2001 Census for to develop commuting matrices. For non-commute purposes, synthetic demand matrices have been derived in such a way that when demands for fully observed cells of the synthetic matrix are replaced with the actual observed demands, trip end targets and consequently trip length distributions remain relatively unchanged, giving credibility to the approach taken to producing the synthetic demand matrix. Demand matrices for the non-commute purposes have first been derived for average hours and subsequently converted to peak hours for the morning and evening time periods, using conversion factors derived from the RIS and disaggregated by purpose and time period.

2.4 MVA believe the method we have used is robust because:

- we have used separate gravity models for each purpose and time period to reflect differences in travel patterns;
- a good fit to observed trip length distributions has been obtained;
- ensured consistency between the average hour models (used within the VDM) and peak hour models; and
- facilitated consistent application in forecasting mode for new developments.

2.5 Commute matrices have been derived by TfGM HFAS directly from 2001 Census travel to work matrices, controlling RIS sector to sector trip totals to screen line traffic counts. Further, TfGM HFAS have produced demand matrices for freight matrices, distributing demands using data from MDS Transmodal's GBfM freight model. TfGM HFAS's work is described in the SATURN model validation report..

[1] An Area of Interest (AofI) was defined for the appraisal of the SEMMMS relief road using an interim version of the SATURN model. AofI is the geographic area over which significant changes in highway flows were predicted as a result of implementing the relief road.

3 Summary of Approach

3.1 The broad approach can be summarised as follows:

Home Based Purpose Trip Ends

- Derive trip rates from the GMATS Household Interview Survey (HIS) by 32 household categories, 10 home based purposes and for each of the 4 modelled time periods included in SEMMMS VDM.
- Derive production trip end estimates for each home based purpose and time period by combining the trip rates with zonal population extracted from the 2001 Census at OA output area, disaggregated to the SEMMMS8 1080 zone system using Code-Point data and converted to a 2009 forecast using growth factors extracted from TEMPRO 6.1.
- Derive attraction trip end estimates by splitting total home based productions for each purpose and time period using purpose/time period specific attraction weights. Attraction weights are derived by disaggregating TEMPRO zone attraction data (from TEMPRO 6.1) to the SEMMMS8 1080 zone system using purpose specific land-use data.

Non-Home Based Purpose Trip Ends

- Derive appropriate trip rates from GMATS HIS to calculate total non-home based trips by purpose and time period.
- Total non-home based trips by purpose and time period are disaggregated symmetrically to origin and destination trip ends at the SEMMMS8 1080 zone level, using a set of weights. These weights are derived from home based trip attractions by purpose, themselves weighted to reflect the propensity of a non-home based trip to be undertaken following a particular home based purpose. These home based to non-home based purpose relationships were derived using trip chain data extracted from GMATS HIS.

Distributions

- Gravity models have been calibrated separately by mode and purpose using Citilabs MVGRAM software in 'forecasting' mode whilst controlling forecasts to target trip ends. Parameters were manipulated on a trial and error basis in order to produce mean trip lengths that are broadly comparable to those suggested by Transport Statistics Great Britain.
- "K-factors" have been calculated for the RIS sector to sector matrix and used in a second synthesis to improve the match of the observed and synthetic demands for cells of the matrix for which demand has been observed.
- The second synthetic demand forecast for the whole matrix is made, controlling forecasts to target trip ends and demands at the RIS sector to sector level using the K-factors.
- The fully observed cells in the second synthetic demand forecast are then overwritten with the fully observed data from the RIS.

4 Roadside Interview Surveys

4.1 TfGM HFAS have derived observed highway matrices using data from a number of RIS surveys undertaken over recent years (SEMMMS, JETTS, GMATS and M60 After Study). The most recent RIS surveys were those shown in Figure 3.1 as cordons 18 and 19, which were undertaken in October 2009 specifically to facilitate the development of SEMMMS8 SATURN models. The remaining RIS data dates from 2003/4. Note that Sector 20 represents the rest of the model, the whole of the area outside all other cordons.

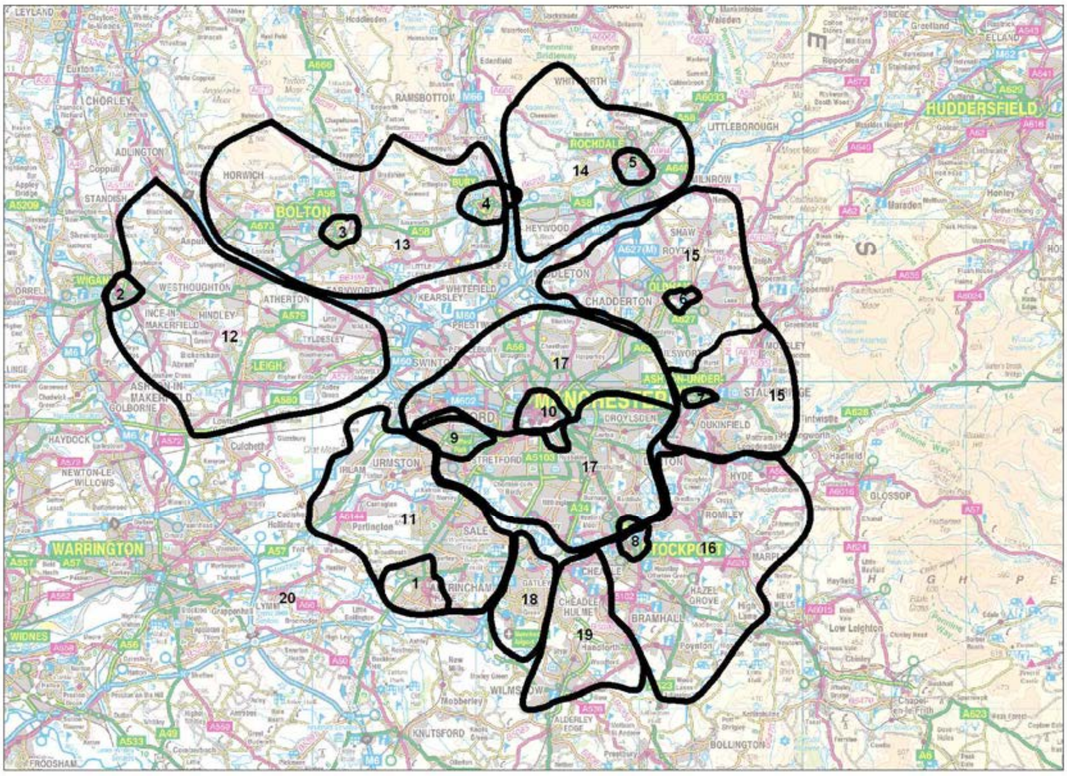

Figure 4.1 Roadside Interview Survey cordons used for highway demand matrix building (OS Licence number: LA100019571)

5 Trip Ends

Preparation

5.1 Different approaches have been taken to producing trip ends for home based productions and attractions, and for non-home based origin/destination trip ends. Home based production trip ends have been derived separately by purpose and time period by combining trip rates and zonal population estimates. Trip rates have been derived from the GMATS HIS disaggregated by 32 household categories, 12 home based purposes (including commute) and for each of the 4 modelling time periods included in SEMMMS VDM (see Appendix A for segmentation definitions). Zonal population data has been extracted from the 2001 Census at OA output area, and disaggregated to the SEMMMS8 1080 zone system using Code-Point data. Growth factors derived from TEMPRO 6.1 have been used to convert the zonal population from 2001 to 2009 estimates.

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5.2 Attraction trip end estimates have been produced by splitting total home based productions for each purpose and time period using purpose/time period specific attraction weights. Attraction weights are derived by disaggregating TEMPRO zone attraction data (from TEMPRO 6.2) to the SEMMMS8 1080 zone system using purpose specific land-use data. The purpose specific land-use data used for each of the non-commute home based purposes were:

- education – based on education jobs;
- shopping – based on wholesale and retail jobs;
- other – based on daytime population;
- employer's business – based on total jobs.

5.3 Day time population was extracted directly from the 2001 Census data whilst other weights were derived from data supplied previously to MVA by David Simmonds Consultancy and used in the preparation of GMSPM2 demand matrices.

5.4 Total non-home based trips by purpose and time period are disaggregated symmetrically to origin and destination trip ends at the 1080 zone level, using a set of weights. These weights are derived from home based trip attractions by purpose, themselves weighted to reflect the propensity of a non-home based trip to be undertaken following a particular home based purpose. These home based to non-home based purpose relationships were derived using trip chain data extracted from GMATS HIS.

6 Distribution Model Forms

6.1 Citilabs MVGRAM software can be used in calibration or forecasting mode to estimate or apply cost deterrence functions relating demands and costs of the general form:

$$T_{ij} = a_i b_j P_i A_j F(C_{ij})$$

where

- T_{ij} = trips estimated from zone i to zone j;
- P_i = productions from zone i;
- A_j = attractions to zone j;
- a_i, b_j = row/column balancing factors; and
- $F(C_{ij})$ = cost deterrence from zone i to zone j.

6.2 More specifically, the software can be used to produce estimates for coefficients X_1 and X_2 in the function:

$$F(C_{ij}) = C_{ij}^{X_1} \exp(X_2 C_{ij})$$

where

- $F(C_{ij})$ = cost deterrence from zone i to zone j;

- C_{ij} = generalised cost from zone i to zone j;
- X_1, X_2 = coefficients to be calibrated.

6.3 If X_1>0 and X_2<0 then a 'gamma' curve is given (see Figure 5.1). The 'gamma' curve describes the trip length distribution typically used in transport modelling. This distribution has been observed particularly for urban areas and in the case of motorised trips. This curve suggests there are few low cost trips, followed by a larger number of medium cost trips. As cost increases, the number of trip decays again with a few very long trips.

6.4 If X_1=0 and X_2<0 then the curve is exponential. This curve reproduces reasonably well the second (or decaying) part of the curve but not the first. If X_2=0 and X_1>0, then the curve is a power function, which reproduces well the first part of the curve but not the second.

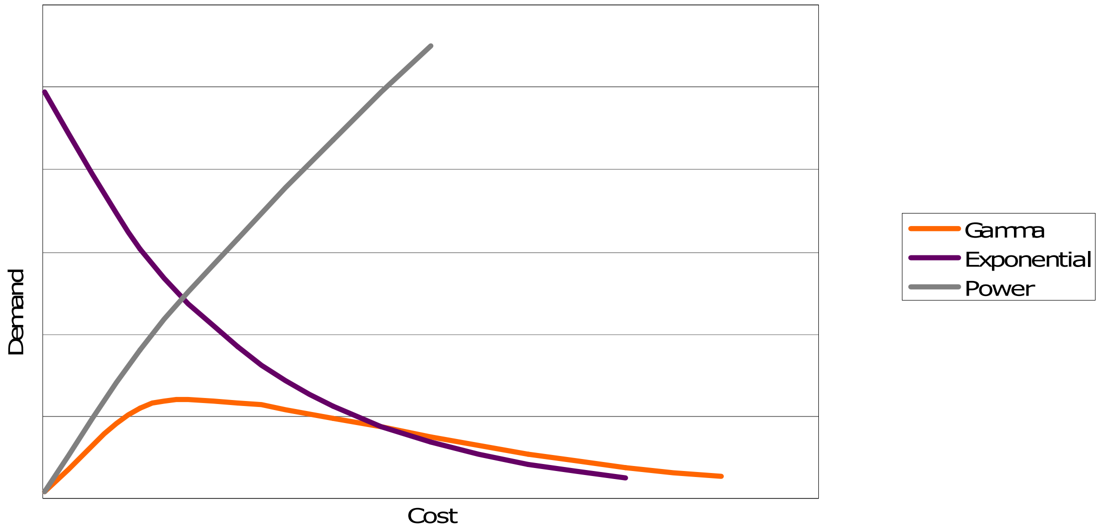

Figure 6.1 MVGRAM Cost Deterrence Functions

6.5 MVA initially tried to estimate separate gravity models for each purpose and time period using demands for fully observed movements in the RIS. However, when used in forecasting mode these models did not reproduce a good match to published mean trip lengths by mode and purpose from the National Transport Survey (NTS). Application of models estimated from the observed demand data consistently overestimated mean trip lengths when applied across the whole matrix, and in particular to the larger buffer zones that cover much of the north of England outside Greater Manchester.

6.6 MVA therefore undertook an alternative approach in which X_1 was set to zero to give an exponential curve and X_2 was manipulated on a trial and error basis until a synthetic demand estimate could be produced, whilst controlling estimates to target trip ends, which reflected plausible mean trip lengths.

7 Calibration & Forecasting Procedures

7.1 Separate models were calibrated for each of the 10 purposes using distance (skimmed from the assignment models) as a proxy for cost, which were then applied for each of the 10 purposes and 3 time periods (30 models in total).

Table 7.1 Calibrated MVGRAM Parameters

Purpose	X1 Value	X2 Value
Education	0	-0.150
Shop	0	-0.150
Other	0	-0.100
Business	0	-0.035

7.2 MVGRAM was run twice in forecasting mode for each purpose and time period. The first run produced an initial estimate of the synthetic demand matrix. K-Factors were then calculated on the 20 cordon sector level to enhance the match of demands estimated with the gravity model to those in the fully observed cells of the matrix. MVGRAM was then run again in forecasting mode, this time including the K-Factors. This step was required to ensure that trip end targets and consequently trip length distributions remained relatively unchanged when demands for fully observed cells of the matrix were replaced with actual observed demands. This was the final step required to produce a full prior matrix estimation demand matrix. Matrix estimation was undertaken on this prior matrix to produce the final validated highway matrices.

7.3 The form of the cost deterrence function including the K-Factor term is:

$$T_{ij} = a_i b_j P_i A_j F(C_{ij}) K_{IJ}$$

where

- T_{ij} = trips estimated from zone i to zone j;
- P_i = productions from zone i;
- A_j = attractions to zone j;
- a_i, b_j = row/column balancing factors;
- $F(C_{ij})$ = cost deterrence from zone i to zone j; and
- K_{IJ} = K-factor from RIS sector I to sector J.

7.4 K-factors are calculated as follows, using the output matrix from the first forecasting run of MVGRAM:

$$K_{IJ} = \frac{T_{IJ}^{RIS}}{T_{IJ}^{MVGRAM}}$$

8 Matrix Analyses

Matrix Totals

8.1 Table 8.1 shows the purpose proportions by time period for fully observed demand movements, based on average hour person trips. As one would expect, commuting forms a larger proportion of trip making during the morning and evening time periods than the inter peak.

Table 8.1 Purpose Proportions by Time Period for Fully Observed Demand Movements (Based on Average Hour Person Trips)

Purpose	Morning	Inter-peak	Evening
Home Based Work	52%	13%	35%
Home Based Employers Business	4%	4%	3%
Home Based Education	7%	3%	4%
Home Based Shop	3%	21%	12%
Home Based Other	20%	28%	29%
Non-Home Based Employers Business	3%	11%	3%
Non-Home Based Other	11%	21%	14%
Totals	**100%**	**100%**	**100%**

8.2 Table 8.2 shows 12 hour car person trip totals for the whole matrix, prior to matrix estimation. Purpose shares for the SEMMMS matrices are shown together with those values derived from TEMPRO 6.1 and shares can be seen to be broadly equivalent.

8.3 However, there are some noticeable differences between the SEMMMS matrices and TEMPRO for the "other" purposes. That said, there is greater consistency between the SEMMMS (75%) and TEMPRO (68%) shares for other purposes than when shares are presented separately by education, shop and other. The segmentation of purposes between education, shop and other in the SEMMMS matrices reflects the differential trip rates derived from the GMATS household interview survey and although matrices have been derived at this more disaggregated level, ultimately all these purpose are combined into a single user class within the demand and assignment models of SEMMMS VDM.

Table 8.2 Comparison of 12 hour Car Person Trip Totals (Prior to Matrix Estimation) with TEMPRO

Purpose	SEMMMS 12-hour Matrix Totals	SEMMMS 12-hour Purpose Share	TEMPRO Purpose shares for GM	Percentage Observed
Home Based Work	4,149,179	22%	27%	14%
Home Based Employers Business	382,294	2%	3%	21%
Home Based Education	1,182,442	6%	9%	7%
Home Based Shop	2,449,690	13%	17%	15%
Home Based Other	7,538,402	39%	33%	8%
Non-Home Based Employers Business	293,986	2%	2%	60%
Non-Home Based Other	3,202,527	17%	9%	14%
Totals	**19,198,519**	**100%**	**100%**	**12%**

8.3.1 Table 8.3 shows 12 hour car person trip totals for trips to/from and within the AofI, prior to matrix estimation. The area for which full representations of travel demand are included in the model contains a population four times the 2.5 million population of Greater Manchester. Consequently, despite the geographical coverage of the RIS cordons only 12% of car trip making in the whole model has been observed (see Table 8.2). However, the proportion of demand to/from and within the AofI that has been observed is considerably higher at 29% (see Table 8.3). Despite this a large proportion of the car demand matrix required synthesis.

Table 8.3 12 Hour Synthetic Car Person Trip Totals For Trips To/From and Within the AofI

Purpose	12-hour Synthetic Matrix Total	Purpose Share	Percentage Observed
Home to Work	428,622	17%	39%
Home to Employers Business	48,997	2%	45%
Home to Education	119,420	5%	21%
Home to Shop	279,372	16%	30%
Home to Other	783,080	38%	23%
Non-Home Based Employers Business	55,152	3%	68%
Non-Home Based Other	373,143	19%	26%
Totals	**2,087,786**	**100%**	**29%**

Mean Trip Length Summaries

8.4 Tables 8.4 and 8.5 show mean trip lengths by purpose and time period calculated for trips in the whole model and those to/from and within the AofI respectively. As one would expect mean trip lengths are significantly higher for business trips than for commute and other purposes. Mean trip lengths are broadly consistent across time periods within a particular purpose.

8.5 The whole model mean trip length values contain trip lengths associated with intrazonal trips for the larger zones beyond the AofI and the rest of Greater Manchester, which have below average trip length. These trips are not included by definition in the to/from and within the AofI values. Consequently, the whole model mean trip length is lower than that for trips to/from and within the AofI.

Table 8.4 Average Trip Lengths for the Whole Model by Purpose and Time Period

Purpose	AM	IP	PM	12-Hour
Commute	10.2	7.3	11.3	9.8
Business	33.7	28.1	32.7	30.7
Other	11.4	11.1	12.5	11.5
All Purposes	**11.8**	**11.2**	**12.9**	**11.8**

Table 8.5 Average Trip Lengths for Trips To/From and Within the AofI by Purpose and Time Period

Purpose	AM	IP	PM	12-Hour
Commute	13.4	11.1	14.4	12.6
Business	28.9	21.4	24.4	22.5
Other	11.1	11.4	12.5	11.6
All Purposes	**12.7**	**12.0**	**13.5**	**12.3**

8.6 NTS suggests an average trip length for car users across all purposes of approximately 13.5km, which is comparable with the values presented above for the SEMMMS assignment models.

9 Conclusions

9.1 In conclusion, we have employed a recommended method for infilling trips for unobserved movements in the car matrices using a gravity model. The analysis given shows that purpose shares are plausible and broadly comparable with those suggested by TEMPRO and that mean trip lengths are broadly comparable with those suggested by NTS.

Appendix A Segmentation Definitions

SEMMMS VDM Time Periods

9.2 Four time periods are included in SEMMMS VDM, which cover 16 hours of a typical weekday. These are:

- AM Peak 0700-0930 2.5 hrs
- Inter-peak 0930-1600 6.5 hrs
- PM Peak 1600-1900 3.0 hrs
- Off-peak 1900-2300 4.0hrs
- Total 16.0 hrs

GMATS Household/Person Type Trip Tate Categories

9.3 Household/Person type trip rates have been derived from GMATS disaggregated by 32 categories. These comprise all combinations of 8 household categories by 4 person types:

Table 1 Household/Person Type Trip Rate Categories

Household Category	Person Type
One Adult, No Car	Children
One Adult, 1+ Car	Workers
Two Adults, No Car	Non-Worker
Two Adults, 1 Car	Retired
Two Adults, 2+ Car	
Three Adults, No Car	
Three Adults, 1 Car	
Three Adults, 2+ Car	

Trip End Purpose Segmentation

9.4 Trip ends have been derived segmented by 12 purposes. These are:

- home to work;
- work to home;
- home to education;
- education to home;

- home to shop;
- shop to home;
- home to other;
- other to home;
- non home based employers business;
- non home based other;
- home to employers business; and
- employers business to home.

Appendix B – Demand Model Calibration for SEMMMS7C

Realism Testing

1.1.1 Model calibration has concentrated on calibrating the response to three tests:

- increasing fuel costs by10%;
- increasing PT fare by 10%; and
- increasing car journey time by 10%.

1.1.2 The outturn elasticity values that TAG suggests should be achieved from these tests are fuel price elasticity between -0.25 and -0.35 (car-kms with respect to fuel price), with commute trips being less elastic than the more discretional purposes. The suggested medium term PT fare elasticity value should be in the range -0.2 to -0.9 (PT trips with respect to fare). Elasticities have been measured using an arc formulation as recommended in TAG Unit 3.10.4:

$$e = \frac{\ln(d^1 / d^0)}{\ln(c^1 / c^0)}$$

where d^1 and d^0 represent demand in base and test scenarios, and c^1 and c^0 represent corresponding costs.

1.1.3 Calibration was undertaken in a structured fashion as follows:

- Test 1. Realism tests were run using the illustrative parameters, but without iterating the demand model. As recommended in TAG Distance Based Cost Damping (DBCD) was not used in Test 1. This gave a quick indication of how closely the model, with the illustrative parameters, would reproduce the target elasticities. The impact of converging the model system on parameters was established in a later step.
- Test 2. DBCD was introduced.
- Test 3. The VDM was run to convergence.
- Test 4. Adjustments were made to the parameters, within bounds recommended by TAG, in order to reproduce the target elasticities.

Test 1. Illustrative Parameters. No DBCD. No Convergence

1.1.4 The starting point for the demand model calibration was the median TAG illustrative parameters. Table shows these parameters by purpose as they would be input to the demand model. Note that home based destination choice parameters are halved for input to the SEMMMS VDM demand model as it operates in terms of 2-way tour costs rather than 1-way trip costs (TAG 3.10.4, 1.7.12).

Table 1 Median TAG parameters input to SEMMMS VDM demand model

Purpose	Median Logit Model Parameters				
	Lambda Values (λ)			Scaling Parameters (θ)	
	Car Dest'n	PT Dest'n	Walk/cycle Destination	Mode	Macro Time
HB Commute	-0.0325	-0.0165	-0.0325	0.68	1
HB Employers Business	-0.0335	-0.0180	-0.0335	0.45	1
HB Other	-0.0450	-0.0180	-0.0450	0.53	1
NHB Employers Business	-0.0810	-0.0420	-0.0810	0.73	1
NHB Other	-0.0770	-0.0330	-0.0770	0.81	1

1.1.5 Consistent with TAG advice, the initial fuel price and PT fare realism tests were produced without any damping of costs (TAG 3.10.4, 1.6.9). The SEMMMS VDM system has a modular structure enabling elasticity values to be calculated after each supply/demand loop through the system.

1.1.6 Table 2 shows the outturn elasticity values for the fuel price and fare realism tests given separately by purpose and time period after the first run of the demand model, before the second reassignments of the supply models. Results are presented for demand to/from and within the AofI of the scheme and for the whole model.

Table 1 Test 1 Fuel Price and PT Fare Realism Test Results

	Test 1: Median TAG parameters, no cost damping, single pass of demand model			
	Car Fuel Vehicle Km Elasticity Values		PT Fare Trip Elasticity Values	
	To/from/ within AofI	Whole Model	To/from/ within AofI	Whole Model
HB Commute	-0.76	-0.54	-0.29	-0.24
HB Employers Business	-0.23	-0.18	-0.05	-0.04
HB Other	-0.76	-0.45	-0.29	-0.22
NHB Employers Business	-0.21	-0.23	-0.08	-0.07
NHB Other	-0.68	-0.48	-0.40	-0.38
All Purposes	**-0.70**	**-0.46**	**-0.29**	**-0.24**
AM	-0.74	-0.48	-0.30	-0.23
IP	-0.69	-0.44	-0.28	-0.23
PM	-0.78	-0.50	-0.29	-0.24
OP	-0.61	-0.42	-0.35	-0.29

1.1.7 The fuel price elasticity aggregate over all purposes and for the whole model (-0.46) is outside the TAG range (-0.25 to -0.35). It is appropriate to consider the whole model elasticity when comparing the outturns of the realism tests with the suggested ranges published in TAG, as SEMMMS VDM contains a full representation of travel demand across all but the 15 external zones, and a mechanism of cost change response has been included for the large buffer zones, which cover much of the north of England beyond the AofI and Greater Manchester.

1.1.8 The PT fare elasticity for the whole model is -0.24, which is at the lower end of the TAG range (-0.2 to -0.9).

1.1.9 Table **2** shows the fuel price elasticity values for Test 1 aggregate over all purposes on a 4x4 sector basis. The four sectors are AofI, rest of Greater Manchester, buffer and external. As might be expected, longer distance movements are more elastic than shorter ones, reflecting the fact that longer distance trips are differentially impacted by the larger absolute cost changes of a percentage rise in fuel price, and a fuel cost increase will tend to lead to a change in destination choice (the most sensitive response) to nearer zones. Further, responses are highly symmetrical, for this presentation of OD sectored elasticity values. Vehicle kilometres associated with relatively short distance trips within the AofI are essentially inelastic (-0.01). However, the elasticity values from the AofI to the buffer area (-1.00) and to the external area (-2.62) appear implausibly high. For this reason, we chose to introduce an element of cost damping to the SEMMMS VDM demand model in subsequent calibration tests.

Table 2 Test 1 Fuel Price Elasticity Values (No Cost Damping)

	AofI	Rest Of GM	Buffer	External
AofI	-0.01	-0.38	-1.00	-2.62
Rest Of GM	-0.40	-0.17	-1.03	-2.84
Buffer	-1.00	-1.02	-0.34	0.00
External	-1.85	-2.12	0.00	0.00

Test 2. Introduction of DBCD

1.1.10 Test 2 uses median TAG parameters and cost damping as defined in paragraphs 6.4.7-10. Movements with an external zone trip end have been made relatively inelastic using a α value of 2.5. For all other movements a α value of 0.5 has been used, the recommended value suggested by TAG. Fuel and fare elasticities are shown in Table 7.6.

Table 3 Test 2 Fuel Price and PT Fare Realism Test Results

	Test 2: Median TAG parameters, cost damping (α=0.5, k=30,d´=30km) , demand model loop 1			
	Car Fuel Vehicle Km Elasticity Values		PT Fare Trip Elasticity Values	
	To/from/ within AofI	Whole Model	To/from/ within AofI	Whole Model
HB Commute	-0.66	-0.48	-0.43	-0.31
HB Employers Business	-0.08	-0.09	-0.23	-0.14
HB Other	-0.55	-0.38	-0.38	-0.25
NHB Employers Business	-0.07	-0.10	-0.24	-0.24
NHB Other	-0.46	-0.39	-0.47	-0.43
All Purposes	**-0.52**	**-0.38**	**-0.40**	**-0.28**
AM	-0.39	-0.25	-0.42	-0.28
IP	-0.39	-0.26	-0.36	-0.26
PM	-0.42	-0.27	-0.41	-0.29
OP	-0.51	-0.36	-0.46	-0.38

1.1.11 The fuel price elasticity aggregate over all purposes for the first run of the demand model reduced to -0.38, still slightly above the TAG range (-0.25 to -0.35). The PT fare elasticity for the whole model once cost damping was applied rose to -0.28.

1.1.12 Table 5 shows the elasticity values for this fuel price realism test after one demand model run on the 4x4 sector system. These values appear much more plausible once cost damping is applied. The vehicle kilometre elasticity value with respect to fuel price for trips from the AofI to the buffer area reduced to -0.86.

Table 4 Test 2 Demand Loop 1 Fuel Price Elasticity Values (With Cost Damping)

	AofI	Rest Of GM	Buffer	External
AofI	-0.02	-0.36	-0.86	-0.19
Rest Of GM	-0.38	-0.17	-0.89	-0.22
Buffer	-0.86	-0.88	-0.31	-0.60
External	-0.15	-0.18	-0.60	0.00

Test 3. VDM Run to Convergence

1.1.13 Elasticity results for Test 3 when the realism tests were run to convergence are shown in Table 56. The fuel price elasticity reduced further to -0.28, within the suggested TAG range. As would be expected the PT fare elasticity was relatively unaffected by changes in modest road speeds between iterations.

Table 5 Test 3 Fuel Price and PT Fare Realism Test Results

	Test 3: Median TAG parameters, cost damping (α=0.5, k=30,d´=30km) , converged demand model			
	Car Fuel Vehicle Km Elasticity Values		PT Fare Trip Elasticity Values	
	To/from/ within AofI	Whole Model	To/from/ within AofI	Whole Model
HB Commute	-0.53	-0.38	-0.42	-0.31
HB Employers Business	0.02	0.06	-0.22	-0.14
HB Other	-0.45	-0.29	-0.37	-0.25
NHB Employers Business	0.00	0.05	-0.23	-0.23
NHB Other	-0.37	-0.27	-0.46	-0.43
All Purposes	**-0.42**	**-0.28**	**-0.39**	**-0.28**
AM	-0.39	-0.25	-0.42	-0.28
IP	-0.39	-0.26	-0.36	-0.26
PM	-0.42	-0.27	-0.41	-0.29
OP	-0.51	-0.36	-0.46	-0.38

1.1.14 Table 77 shows the elasticity values for the fuel price realism test at convergence on the 4x4 sector system. Elasticity values for longer distance trips reduce as the model is run to convergence, reflecting the reduced impacts of congestion relief between the first run of the demand model and the final converged solution.

Table 6 Test 3 Converged Model Fuel Price Elasticity Values (With Cost Damping)

	AofI	Rest Of GM	Buffer	External
AofI	-0.03	-0.30	-0.66	-0.20
Rest Of GM	-0.32	-0.14	-0.62	-0.23
Buffer	-0.68	-0.62	-0.23	-0.59
External	-0.16	-0.18	-0.59	0.00

Test 4. Final Results of Demand Model Calibration

1.1.15 In a final calibration step, adjustments were made to some of the demand model parameters to improve the relativity of outturn elasticity values by purpose. To this end, the car commute destination parameter was reduced whilst the car home based other and non home based other destination parameters were increased. This was done to ensure the fuel price elasticity value for commute was less than those of the more discretionary purposes. The commute parameter was reduced to its minimum values (17% less than the median values) and the home based other and non home based other parameters were increased by 25%, the maximum relative change from the median value readily permitted by TAG (TAG 3.10.4, 1.7.11).

1.1.16 Similarly the PT destination parameter for home based other was increased by 25% in order to make the PT fare elasticity value for home based other more elastic than that for commute.

1.1.17 The final parameters input to the demand model are shown in Table 8 and the outturn fuel price and PT fare elasticity values in Table 9.

1.1.18 **The final fuel price elasticity value aggregate over all purposes for the whole model was -0.3 and PT fare elasticity was -0.44.**

Table 7 Final parameters input to SEMMMS VDM demand model (red values have been adjusted away from the median TAG values)

Purpose	Median Logit Model Parameters				
	Lambda Values (λ)			Scaling Parameters (θ)	
	Car Dest'n	PT Dest'n	Walk/cycle Destination	Mode	Macro Time
HB Commute	-0.0270	-0.0165	-0.0325	0.68	1
HB Employers Business	-0.0335	-0.0180	-0.0335	0.45	1
HB Other	-0.0563	-0.0225	-0.0450	0.53	1
NHB Employers Business	-0.0810	-0.0420	-0.0810	0.73	1
NHB Other	-0.0963	-0.0330	-0.0770	0.81	1

Table 8 Test 4 Fuel Price and PT Fare Realism Test Results

	Test 4: Final parameters, cost damping (α=0.5, k=30,d´=30km), converged demand model			
	Car Fuel Vehicle Km Elasticity Values		PT Fare Trip Elasticity Values	
	To/from/ within AofI	Whole Model	To/from/ within AofI	Whole Model
HB Commute	-0.43	-0.32	-0.52	-0.39
HB Employers Business	0.01	0.06	-0.26	-0.19
HB Other	-0.54	-0.35	-0.67	-0.46
NHB Employers Business	0.00	0.05	-0.38	-0.36
NHB Other	-0.41	-0.33	-0.66	-0.55
All Purposes	**-0.43**	**-0.30**	**-0.60**	**-0.44**
AM	-0.37	-0.26	-0.58	-0.43
IP	-0.42	-0.29	-0.61	-0.45
PM	-0.42	-0.28	-0.59	-0.44
OP	-0.53	-0.39	-0.78	-0.56

1.1.19 As anticipated elasticity values for both fuel price and PT fare are higher in the off-peak than other time periods. However, one might expect lower elasticity values in the peaks than the inter-peak. In fact, in SEMMMS VDM there is little difference between the elasticity values in the AM, IP and PM time periods.

1.1.20 Fuel elasticities for employers business trips are slightly positive. This is because the increase in fuel cost has a greater deterrent effect for the commute and other purposes, which have lower values of time than employers business, and the resulting reduction in congestion counteracts the fuel cost rise for business travellers.

1.1.21 Table 9 shows the PT fare elasticity values disaggregated by household car availability category. TAG 3.10.4, 1.6.24 suggests elasticity values for car available segments might be expected to be greater than those of non car available segments, since the former have greater choice than the latter, and this is the case for SEMMMS VDM.

Table 9 PT Fare Elasticity

	To/from/within AofI	Whole Model
No car available	-0.55	-0.39
Car available	-0.64	-0.49
All categories	**-0.60**	**-0.44**

Car Journey Time Elasticity

1.1.22 TAG 3.10.4, 1.6.27 requires car journey time elasticity values to be calculated based on the change in car trips with respect to a 10% change in journey time. We have calculated car journey time elasticity values by inputting a factored matrix of car travel times, skimmed from the base model, to a single run of the demand model.

1.1.23 As anticipated, journey time elasticity values, shown in Table Table 10, vary much more than the fuel cost elasticity values (TAG 3.10.4, 1.6.30). However, values are not disproportionately high and all are less than -1.0.

Table 10 Test 4 Car Journey Time Realism Test Results

	Median TAG parameters, cost damping (α=0.5, k=30,d´=30km), converged demand model	
	Car Fuel Vehicle Km Elasticity Values	
	To/from/within AofI	Whole Model
HB Commute	-0.52	-0.35
HB Employers Business	-0.26	-0.15
HB Other	-0.44	-0.26
NHB Employers Business	-0.17	-0.12
NHB Other	-0.31	-0.21
All Purposes	**-0.43**	**-0.27**
AM	-0.42	-0.28
IP	-0.34	-0.23
PM	-0.38	-0.22
OP	-0.73	-0.39

Network Based Elasticity Values

1.1.24 TAG 3.10.4, 1.6.12 requires car fuel price elasticity values to be calculated on a network basis, as well as on an OD basis for which results are presented above. TAG suggests that these elasticity value calculations are likely to underestimate the fuel cost elasticity if the change in car vehicle kilometres includes fixed elements.

1.1.25 However, the reverse is the case for SEMMMS VDM. The demand model contains a mechanism whereby cost changes impact on the intrazonal demands of the large buffer zones. Demand changes for intrazonals are by definition relatively short in length. As this demand is not reassigned to the network the overall network based elasticity values are slightly higher than the elasticity values for the whole model calculated on an OD basis.

1.1.26 Whereas the fuel price elasticity value for the whole model calculated on an OD basis is -0.30, the values calculated on a network basis are -0.34, -0.38 and -0.35 for the AM, IP and PM assignment models respectively.

Table 11 Test 4 Network Based Fuel Price Realism Test Results

Time Period	Car Fuel Vehicle Km Elasticity Values
AM	-0.34
IP	-0.38
PM	-0.35

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Abu Dhabi
AS Business Centre, First Floor, Suites 201-213, Al Ain Road, Umm al Nar, P.O. Box 129865, Abu Dhabi, UAE
T: +971 2 558 9809 F: +971 2 558 3809

Birmingham
Second Floor, 37a Waterloo Street
Birmingham B2 5TJ United Kingdom
T: +44 (0)121 233 7680 F: +44 (0)121 233 7681

Dubai
Office 402, Building 49, Dubai Healthcare City
PO Box 123166, Dubai, UAE
T: +971 (0)4 433 0530 F: +971 (0)4 423 3613

Dublin
First Floor, 12/13 Exchange Place
Custom House Docks, IFSC, Dublin 1, Ireland
T: +353 (0)1 542 6000 F: +353 (0)1 542 6001

Edinburgh
Stewart House, Thistle Street, North West Lane
Edinburgh EH2 1BY United Kingdom
T: +44 (0)131 220 6966 F: +44 (0)131 220 6087

Glasgow
Seventh Floor, 78 St Vincent Street
Glasgow G2 5UB United Kingdom
T: +44 (0)141 225 4400 F: +44 (0)141 225 4401

London
Second Floor, 17 Hanover Square
London W1S 1HU United Kingdom
T: +44 (0)20 7529 6500 F: +44 (0)20 7529 6556

Lyon
11, rue de la République, 69001 Lyon, France
T: +33 (0)4 72 10 29 29 F: +33 (0)4 72 10 29 28

Manchester
25th Floor, City Tower, Piccadilly Plaza
Manchester M1 4BT United Kingdom
T: +44 (0)161 236 0282 F: +44 (0)161 236 0095

Marseille
76, rue de la République, 13002 Marseille, France
T: +33 (0)4 91 37 35 15 F: +33 (0)4 91 91 90 14

Paris
12-14, rue Jules César, 75012 Paris, France
T: +33 (0)1 53 17 36 00 F: +33 (0)1 53 17 36 01

Woking
Dukes Court, Duke Street, Woking
Surrey GU21 5BH United Kingdom
T: +44 (0)1483 728051 F: +44 (0)1483 755207

Email: info@mvaconsultancy.com

Offices also in
Bangkok, Beijing, Hong Kong, Shenzhen and Singapore

mvaconsultancy